Advisory Council for Applied Research and Development
in collaboration with
Advisory Board for the Research Councils

Improving research links between Higher Education and Industry

June 1983

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Foreword

1. In June 1982 ACARD were invited by the Prime Minister to prepare a report in collaboration with the Advisory Board for the Research Councils (ABRC) on the links between industry and higher education institutions in the field of research and its application. A Working Group was set up to undertake the study; members of the Working Group were:

*Sir Alan Muir Wood FEng, FRS (Chairman)	Senior Partner, Sir William Halcrow and Partners
*Dr D V Atterton CBE FEng	Chairman, Foseco Minsep Ltd
Dr S L Bragg FEng	formerly Vice-Chancellor, Brunel University
Dr J B Butcher	Head of Microelectronics, Middlesex Polytechnic
Mr P G Davey	Department of Engineering Science, University of Oxford
**Mr J R S Morris FEng	Chairman, Brown and Root (UK) Ltd
Dr J Spreadborough	Managing Director, John Spreadborough and Company Ltd
Professor R Whittenbury	Department of Biological Sciences, University of Warwick

* ACARD member
** ABRC member

2. The terms of reference of the Working Group were—

i. To review current arrangements for co-operation between the universities and other relevant higher education institutions, Research Councils and industry in the fields of research and its applications; and identify examples of good practice.

ii. To assess the effectiveness of these arrangements in providing benefits to both parties.

iii. To examine any institutional, administrative, financial or other barriers and disincentives to the formation, progress and extension of links and the scope for their dismantling.

iv. To consider the implications for Britain of arrangements in other countries.

v. To make recommendations.

3. The Working Group sought evidence and opinion from all universities, polytechnics and other relevant higher education institutions in the UK, from a wide selection of industrial companies and from learned societies and other institutions. In total, 240 written submissions were received. In addition, nearly 60 people were interviewed during visits undertaken by members of the Working Group and its Secretariat.

4. The Working Group's report received the broad agreement of the ABRC in April 1983 and was endorsed by ACARD in May 1983. It was submitted to the Prime Minister, and is now published to draw attention to the recommendations and to stimulate public discussion.

5. ACARD and ABRC gratefully acknowledge the support provided in preparing this report by the ABRC Secretariat in the Department of Education and Science, the Central Policy Review Staff and the ACARD Secretariat in the Cabinet Office.

Summary of conclusions and recommendations

1. The links between industry and higher education institutions (HEIs) in research and its application can contribute significantly to the economic health of the UK. Indeed they must do so, if this country is to benefit from its strong base of science and technology. This is a matter of vital long-term importance.

2. Such links make available to industry the knowledge, expertise and facilities in the institutions and so enhance its capacity for innovation and improvement. They also benefit academic researchers who can participate in the application of their ideas and may thereby be pointed towards other research areas of national importance. This may provide them with a wider range of challenges and can enrich teaching, through experience of current industrial practice.

3. While there are outstanding exceptions, progress in establishing productive links has been slow. Attitudes are changing in favour of more collaborative work between industry and HEIs, but there is still a certain reluctance for the partners to come together. We see four themes as providing the key to progress —

a. Individual institutions differ one from another, each being excellent in particular subject areas or ways of working. Such differentiation should be encouraged. In our view, HEIs themselves should go further than hitherto in deciding what are their strong points in research, and should be given sufficient financial flexibility to follow their chosen path of development.

b. Many of the fundamental investigations carried out in HEI departments in the UK are of the highest intrinsic merit and must continue; we have no desire to undermine excellent research or scholarship of any kind. But it must be admitted that some work may be of less urgency, importance or even interest. Such work, together with an increasing teaching load, has pre-empted resources which might otherwise have been devoted to areas of research which are both academically worthwhile and have industrial relevance. We aim, through a reallocation of research effort within HEIs, for a better balance between basic and more applied research.

c. There must be a corresponding change in the practice and attitudes of individual industrial companies towards collaboration with HEIs. Universities and polytechnics in the UK have knowledge and expertise which can strengthen existing enterprise and generate new business ventures. Foreign firms are well aware of this, and are taking advantage of it.

d. The Government and public sector bodies have an active role to play. They should actively promote collaboration between HEIs and industry, both by providing practical encouragement to each partner and by organising themselves in ways which facilitate co-operation.

4. *We conclude* that, given the steps they are already taking, the initiative in forging new and productive links should lie mainly with the HEIs. Industry will need to match this with a constructive response and initiative of its own. The institutions will need some financial headroom to undertake this task. The first of the recommendations listed below seeks to strengthen HEIs which are already successful in collaborating with industry, as reflected by their income, and the second recommendation aims to bring others to a similar level of success.

5. *Our principal recommendations* (with reference to paragraph numbers) are—

i. The Government should establish an 'industrial seedcorn fund' to support the infrastructure and basic research that will complement effective, industrially-financed applied research. The fund should equal 25% of the money earned by HEIs through contracts, consultancies and investigations from the private sector and the public trading sector (excluding contracts for teaching and training). This would initially require about £10M pa. HEIs should receive allocations from the fund equal to 25% of their eligible earnings. The fund should be established for 5 years in the first instance. Its size should be adjusted annually in order to remain equal to 25% of eligible HEI earnings. (4.17)

ii. A minimum of £5M pa should be earmarked by the Department of Industry (DOI) for an initial period of 5 years to be used for projects proposed by HEIs that contribute significantly to the infrastructure for academic-industrial co-operation. This scheme should be managed jointly by DOI and the Science and Engineering Research Council (SERC). Pump-priming funding should be conditional upon evidence of serious intent by

HEIs to adapt to industrially-oriented work, notably through appropriate conditions of academic appointments. (4.18, 4.19)

iii. Bodies on which industry is represented at a high level — CBI, BIM, NEDO, local Chambers of Commerce and Industry, the Royal Society, Fellowship of Engineering and learned societies — should urge firms to show initiative commensurate with that of the HEIs in establishing and maintaining academic-industrial links, notably by bringing together firms with a common interest in a particular activity, discipline or HEI. Building upon what already exists, the Royal Society for the Encouragement of Arts, Manufactures and Commerce (the RSA), with a membership and objectives highly relevant to this issue, should foster and co-ordinate these activities; the Royal Society of Edinburgh is well-placed to promote such activities in Scotland. (4.25)

iv. DOI and SERC should collaborate more closely in supporting both joint activities carried out by industry-HEI partners and industrially-oriented work in HEIs (we see SERC's directorates as a model); DOI should provide most of the funds for new initiatives in this area, although SERC might administer the schemes; and other Research Councils should consider with appropriate Government Departments the introduction of joint schemes for supporting academic-industrial collaboration. (4.36)

v. The Department of Education and Science (DES), the University Grants Committee (UGC) and other relevant bodies should take action—

a. to agree an appropriate average level of research activity in universities, each university proposing the level which it wishes to adopt;

b. to assure adequate support for research by means of an identified proportion of the UGC grant;

c. to ensure that funds intended for research are used for that purpose;

d. to ensure that research funds are effectively managed by universities by means of Research Committees (as advocated in the Merrison Report) or equivalent bodies. (4.15)

6. *Other recommendations* are—

vi. The Government should mount a campaign, with active Ministerial involvement, to improve awareness of the benefits of academic-industrial collaboration and of the measures available to encourage it. (4.32)

vii. Senior executives of industrial companies and their staffs should seek and accept appointment to bodies through which they can establish links with academics and learn of academic capabilities, and that they should actively follow up the academic contacts so established. (4.26)

viii. DES in consultation with the Department of the Environment (DOE) and other appropriate bodies should take action to provide—

a. a clearer definition of the role of polytechnics with regard to research, notably that supportive of industrial contacts;

b. an identified amount for research activity, analogous to UGC support of universities;

c. an amendment of the law in order to allow polytechnics to negotiate contracts and undertake consultancies. (4.23)

ix. SERC, in collaboration as appropriate with DOI and others, should establish a national database of HEI research capabilities, accessible to the public by means of viewdata. The DOI and SERC should jointly set up a national system of regional brokers as an adjunct to the national database and to promote the support available for innovation and academic-industrial partnerships. Other public sector organisations should be enabled to employ the brokers part-time as agents for their own regional activities. (4.38, 4.39)

x. DOI should give special treatment in its support schemes to those projects of appropriate merit which involve academic-industrial co-operation. (4.29)

xi. HEIs should normally have the direct responsibility for ensuring that inventions arising from publicly-funded research are exploited. Any proceeds accruing to the institution, whether from royalty income or joint ventures or whatever, should remain with it and not be offset by any clawback arrangement, overt or covert. (4.27)

xii. DOI should establish a scheme whereby academics can take extended 'exploitation leave' in small companies with a guaranteed right of return to their institution, with DOI paying for a substitute member of academic staff during their absence from the institution. SERC and the Royal Society should more vigorously promote their Industrial Fellowship scheme for mobility between firms and HEIs and other bodies well-placed to promote mobility should establish similar schemes. (4.31)

xiii. The Research Councils should review their procedures for making post-graduate training awards in order to ensure they contribute in the most effective way to concentration and selectivity in research. (4.21)

7. We have also made a number of other suggestions and comments which may call for action:

a. HEIs should only charge for their services at less than full economic rates if there are special academic reasons for doing so. (3.14)

b. Those who change job should retain pension rights commensurate with their own and their employer's contributions. (3.18)

c. There should be greater flexibility in the conditions of employment of academics. (3.19)

d. Industrial work should be a factor in academic promotions. (3.22)

e. DOI should ensure that business advice is available to academics. (3.27)

f. A study of the creation of successful new firms around Cambridge should be commissioned. (3.28)

g. The objectives of science parks and the means of achieving them should be clearly established and published by those involved. (3.32)

h. SERC should assess its Integrated Graduate Development Scheme in consultation with the Engineering Council. (3.34)

i. More attention should be paid to the industrial definition of PhD projects and to part-time PhD work. (3.35)

8. We believe that there is the potential for a substantial strengthening of links between HEIs and industry in this country and that action should be considered as a matter of urgency.

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1 Introduction

Research, knowledge and society

1.1 The UK possesses great strength in the quality and breadth of its academic research, and in the ability of academic researchers. Research contributes to knowledge, which is then accessible worldwide either through professional contacts or through publications and conferences. The nation's industrial effort needs to be able to exploit the practical applications of this research, which underpins the innovation needed in any thriving industry.

1.2 The Working Group's main premise is that knowledge generated by research in science and engineering should be effectively applied to benefit the society which sustains the research effort. Occasionally, (eg in the case of vitamins and antibiotics) the benefits from new discovery are so spectacular and obvious that links to production and widespread availability are purposefully forged. More generally, the pathways between the advance of knowledge and its practical application are less obvious. Clear signposting is required to provide well defined lines of communication between researchers and industry. There can never be an entirely tidy correspondence between discipline-oriented researchers and mission-oriented industry.

1.3 Our remit focusses on *higher education institutions* (HEIs) as one major source of advances in knowledge, and *industry* as the agent by which these can be converted into products or services which meet the needs of society and for which society is prepared to pay. Universities and polytechnics are not, of course, solely concerned with research, but in practice the research and teaching functions are strongly related and much research is carried out against the background of a close and valuable interaction with teaching.

Academic-industrial links in research and its application

1.4 This subject is especially topical because both industry and the higher education sector are seeking to maintain scientific and engineering capability in stringent financial circumstances. Both, therefore, stand to gain from better links. At the same time, improved exploitation of technology can contribute significantly to economic prosperity, and thereby increase the resources available for supporting science and technology within both industry and higher education.

1.5 Links between industry and higher education carry two-way traffic. In one direction, they assist the development and exploitation of research results; provide opportunities for researchers to be involved in the use of their ideas; and offer a much wider reservoir of expertise to companies than they could otherwise afford. In the other direction, academic-industrial links help to direct researchers towards areas where benefits to society might appear, without loss of academic merit; provide researchers with a wide range of challenges and experience; and enrich teaching by providing access to current practice. Through such links, industry can use the results of existing research more effectively and can contribute to the identification of areas of future work.

1.6 We are not, of course, the first to consider this subject. Of particular note are the study by the Confederation of British Industry and the Committee of Vice-Chancellors and Principals published in 1970 (the Docksey Report) and the report in 1976 by the House of Commons Select Committee on Science and Technology. However, with certain notable exceptions, the record of achievement in the past 15 years has not been good and further initiative to improve matters is needed.

The scope of this study

1.7 This study considered two complementary questions—

a. how to help mutually sympathetic partners to work together; and

b. how to inculcate and encourage attitudes favouring the development of co-operation.

The first question involves 'marriage broking' to find productive partnerships and maximise their productivity. The second may involve persuasion or even coercion to provoke changes in practice and to widen the experience of those on both sides, thereby changing attitudes and also affecting a wider climate of opinion. In addressing both questions, we have considered what barriers and disincentives exist and how to dismantle or overcome them.

1.8 We have not considered the teaching role of higher education institutions except as it directly affects research and its application. We acknowledge that a major service which HEIs provide to industry is the supply of educated and trained manpower. But that subject — though vitally important — is beyond the scope of this study.

1.9 Most of our evidence concerned research in the natural sciences and in engineering. Medicine and agriculture, in the UK as in other countries, have tended to evolve their own distinctive means for linking research with application, and teaching with practice. We are also aware of links in the social sciences. But we believe that, even though our attention may tend towards engineering, the measures we propose in Chapter 4 will benefit academic-industrial links across the spectrum of academic and industrial activities.

1.10 The second chapter of this report summarises the present UK arrangements for academic-industrial collaboration in research and its application. The third presents our analysis and discussion, and the fourth our conclusions and recommendations. A summary of the main points in the written evidence we received is in Annex 1. Some noteworthy overseas arrangements are described in Annex 2. A list of contributors to the report is at Annex 4.

2 Current higher education — industry links in the UK

2.1 Industry, higher education institutions (HEIs) and other interested parties have devised many kinds of links for the purpose of undertaking research and promoting its application. Individual academics and industrialists have set up many arrangements themselves, but a number of schemes are promoted by third parties. Pre-eminent examples are the schemes run by the Science and Engineering Research Council (SERC) but other Councils have some similar schemes. Others involve the British Technology Group (BTG) which incorporates the formerly independent National Research Development Corporation (NRDC). In this section of the report, we review the principal academic-industrial links — dividing them into direct contacts and third party measures.

The general context

2.2 In 1978 (the latest year for which complete figures are available), some £3,500M was spent on R and D in the UK. Private industry funded about 36% (£1,280M) and carried out 59% (£2,060M) of the work, most of the remainder coming from the government. Of private industry's £1,280M, £1,180M were spent in its own establishments, £60M in Government establishments, £15M in Research Associations, £6M in HEIs and £17M elsewhere. In addition to £6M from private industry, HEIs also received £6M from public corporations and £8M from overseas, making some £20M in all. Their total funding for R and D was £317M. (More details are given in Table 2.1.)

2.3 Of course, not all industry-HEI contact is concerned with R and D, and there are difficulties with surveys: R and D surveys in industry probably only relate to formal R and D departments; the total HEI R and D expenditure is an estimate based in part on a 12 year old survey of how university staff spend their time. But the figure of about £20M out of £317M does indicate the scale of work for industry in 1978. Our own best estimate of HEIs' overall industrial receipts in 1981/82 is £35-40M. This is based on returns submitted to us by HEIs with the addition of major projects known to us but not covered by the returns.

Table 2.1 *Research and development related to science and technology in each sector according to source of finance*[1] *— 1978*

	£ million							
	Sector carrying out the work							
	Government	Universities and further education establish-ments	Public corporations	Research associations	Private industry	Other	Total performed in the United Kingdom	Research carried out abroad
Sector providing the funds								
Government	646.7	247.1	3.4	13.7	662.6	77.9	1,651.4	164.2
Universities[2]	—	28.4	—	—	—	—	28.4	
Public corporations . .	2.9	6.1	203.1	7.6	39.9	—	259.7	. .
Research associations . .	—	—	—	8.2	—	—	8.2	. .
Private industry	60.8	6.1	0.7	15.0	1,184.5	17.1	1,284.2	. .
Overseas	26.5	8.1	5.3	6.3	173.9	2.5	222.6	
Other	21.2	21.5	—	—	—	13.1	55.8	. .
Total cost of research and development performed . .	758.1	317.3	212.5	50.8	2,061.0	110.6	3,510.3	. .

[1] Research in the social sciences is excluded

[2] Including also further education establishment

Source: Economic Trends, August 1981 (HMSO)

Direct contacts

2.4 The most productive interaction between HEIs and industry occurs through direct personal contact. In specialised research areas related to innovative industries, academics normally know the firms to which their research is particularly relevant and, conversely, industrialists normally know where to obtain academic expertise in their main field of interest. Many of the third party schemes are aimed at fostering existing contacts and making new ones. Direct contacts can produce the two-way exchanges of ideas, expertise and facilities which benefit both parties and the results of academic research can thereby be translated into products and services.

2.5 Industrial companies and HEIs can take steps to foster productive contact between individuals. In addition to the traditional ways, for example endowing academic fellowships or chairs, industrial companies can help institutions by providing advice on technical, research, curricular or business matters; supplying lecturers or other staff; and making available industrial premises or equipment for university research or teaching. In return, HEIs can provide industry with consultancy or contract research facilities, specialist advice and facilities, and special training courses to meet industrial needs. Joint activities such as research programmes with work in both industry and academic institutions, joint seminars, joint appointments, and joint supervision of, for example, sandwich course students can bring individuals together, as well as being productive in their own right. They also provide opportunities for mixed careers in industry and HEIs. Such linkages bring benefits, provided that a single industrial liaison does not so dominate a department's research programme that it unbalances it.

Liaison bureaux and industrial units

2.6 Most universities, and a number of polytechnics, have an industrial liaison unit of some kind, serving particular academic departments or the whole institution. The most modest unit consists of one or two people — full-time or part-time — who handle the administration of academic-industrial collaboration, and provide information to industry on request. Others have more active involvement with marketing the institution's wares, and placing industrial work with appropriate academics.

2.7 Another arrangement is for the unit to operate almost independently of the HEI, having research and workshop staff of its own to undertake elements of industrial work. Such elements might, for example, involve development further downstream than an academic research group would normally go, or work to a timescale not readily accommodated within the HEIs' general activities. Such units do not undertake production work nor, by virtue of the institution's charitable status, can they distribute a surplus. Their staff are employees of the HEI and paid on academic salary scales but there is scope for considerable flexibility in providing performance-related rewards as well.

2.8 In a number of HEIs, the industrial liaison unit takes the form of a company — usually limited by guarantee and wholly owned by the institution. By this means, the unit can operate in a fully commercial profit-making environment with corresponding freedom over staffing and conditions of service. The companies may operate primarily as an interface between industry and their institutions, for example, in arranging and managing contracts. But in at least one case, the company is an entirely free-standing contract R and D organisation: it is under no obligation to use solely institutional consultants and applies no pressure on academics to use the firm for development and exploitation of their ideas. Such wholly-owned companies need to spin off subsidiaries when outside equity participation is called for, for example in a particularly high-risk venture, or in production work where a different business approach is required from that in a contract R and D organisation.

2.9 Many of the units were set up with pump-priming funds from the Wolfson Foundation, or under the schemes operated in the late 1960s and early 1970s by the University Grants Committee and the former Ministry of Technology. In a number of cases, though, the industrial demand was such that no third party support was needed.

New enterprise projects

2.10 One form of new enterprise project is variously known as a science park, technology park or innovation centre. The idea of science parks has been imported from the United States where significant industrial developments have grown up near particular universities. In the UK there are about 10 science parks already existing or being implemented, and others are planned. In general, the concept is for the provision of a site very close to an HEI, where science-based firms can easily interact with the scientific community. The park can also provide 'nesting boxes' for new small enterprises set up to develop and exploit academic ideas.

2.11 The success of these projects has been — and will probably continue to be — variable. In some actual and planned cases, the park is simply a convenient and attractive use for a piece of property owned by the HEI or others, and not necessarily sited close to the institution. On the other hand, the UK has what appears to be the only fully operational science park in Europe to be located on a university campus (Heriot-Watt Research Park). In addition, concentrations of industrial activity are beginning to emerge adjacent to some HEIs or on the campus — at Reading University and Cranfield, for example — but are not being called 'science parks'. In some cases, firms in the park may use common office services and have the use of the social and technical facilities of the academic institution.

2.12 The parks have been initiated variously by HEIs, local authorities, commercial enterprises and (in one case) a central government agency. The funds to establish the park may well come from non-academic sources, particularly if the local authority makes a point of fostering new businesses.

The Science and Engineering Research Council (SERC)

2.13 The Research Councils have a number of schemes to encourage HEI-industry links in operation or planned. Within its broad responsibilities for supporting research and advanced training in higher education institutions in physical and biological sciences and in engineering, SERC has several schemes for increasing academic-industrial interaction. These naturally relate more to engineering than science but are available in both. For the development of industrially-relevant technology, SERC has established four *directorates* and 18 *specially promoted programmes* since 1977. These relate to areas of technology where a concerted attack was likely to produce worthwhile results of national benefit. The objectives of these programmes are defined in consultation with industry, government Departments and active researchers in the field. Two key elements of these programmes are: first, that they are closely managed through the appointment of Directors or Co-ordinators whose functions are to ensure that an appropriate portfolio of research projects is generated and properly managed; and, secondly, that industry is directly involved in the prosecution of the research and is therefore well placed to take up the results. Current SERC expenditure in these areas is about £18M pa.

2.14 The six SERC schemes directly aimed at supporting HEI-industry links are as follows:

— *Co-operative Grants* which support co-operative research carried out in HEIs with a financial contribution from industry;

— *Co-operative Awards in Science and Engineering* which support postgraduate training through research jointly supervised by an academic and an industrialist;

— *Collaborative Training Awards* which support short-term training projects of 12-15 months duration related to the problems of industrial production in smaller companies;
— the *Integrated Graduate Development Scheme* which enables new graduate recruits to manufacturing industry to receive intensive induction training organised jointly by their employer and an HEI;
— the *Teaching Company Scheme* which pays for high calibre graduates to work in an industrial company to solve problems in manufacturing, under the joint supervision of the firm and the HEI;
— the *Royal Society/SERC Industrial Fellowship Scheme* which supports academics seconded to an industrial environment for up to 2 years to undertake a project related to the company's R and D programme, and coversely provides funds for industrialists to undertake research or course development in an HEI.

We now describe these schemes in more detail.

2.15 SERC introduced its *Co-operative Grants Scheme* in 1978 in order to encourage direct industrial involvement in academic research work at an early stage. Under the terms of the grants, the SERC's contribution may be up to three times that of the industrial partner in terms of direct costs. A firm that contributes financially, or through effort or equipment, at least half the resources needed by an academic project receives the rights in the development work, with some small percentage royalty on subsequent sales going to BTG. The scheme has some 180 projects already in progress, to which SERC contributes about £1.5M pa, and a wide variety of firms is involved. In a majority of projects, the firms are contributing well over the required share of the costs; the knowledge that the firm will obtain the exploitation rights is thought to provide a considerable incentive to this level of support. Co-operative grants are often a preferred, and sometimes a required, mechanism for subjects covered by directorates or specially promoted programmes. The Medical Research Council is introducing a similar scheme for the universities in 1984.

.16 The *Co-operative Awards in Science and Engineering (CASE) Scheme* ffers a type of research studentship where an industrial organisation joins ith the university or polytechnic in defining a project, and supervising the tudent's progress. The company also agrees to make its own facilities, ncluding appropriate training in laboratory work, design and manufacture, available to the student for a part of his total training period. This is a method of giving the student a new perspective on the significance of his research in an industrial context, the project being selected jointly by university and industry. It leads to a type of training directly relevant to the industry's interests and training for its staff. In addition, the resulting contact between academic and industrial supervisors can generate new interaction. 760 new CASE awards were made by SERC in 1981, representing about one-third of all its PhD awards. So far, most CASE projects have involved collaboration between an academic department and a research laboratory of one of the larger industrial organisations. The Medical Research Council has a similar scheme. In 1979, SERC introduced the *Collaborative Training Awards Scheme* to support short-term training projects of 12-15 months which were more related to the problems of design and production and more relevant to the needs of smaller companies. The number of projects launched, however, has been small. In addition, the *Integrated Graduate Development Scheme* provides financial support to enable new graduate recruits to manufacturing industry to undergo in their early years intensive induction training organised jointly by the participating companies and a designated university or polytechnic. The training comprises alternating periods in the companies and university, blending academic tuition with practical industrial experience at factory level.

2.17 The *Teaching Company Scheme* is supported jointly by the Department of Industry and SERC, which contribute equally to its funding. The aims of the Scheme are to develop active partnerships between HEIs and manufacturing companies in order to raise manufacturing performance by effective use of academic knowledge and facilities, to improve manufacturing methods by the effective implementation of advanced technology, to encourage able graduates to train for careers in manufacturing, and to develop and retrain staff both in HEIs and the companies. Under the scheme, high calibre graduates are paid to work full-time in a company to solve problems in manufacturing, under the joint supervision of the firm and the HEI. Since the inception of the scheme, more than 95 partnerships have been supported; annual expenditure is about £2.2M.

2.18 The *Royal Society/SERC Industrial Fellowship* scheme was launched in 1981 to enable academics seconded to an industrial environment to undertake a project lasting from 6 months to 2 years related to the company's R and D programme, and to enable industrialists to undertake research or course development in a university or polytechnic. The fundamental aim is to improve understanding of the problems of conducting R and D in the other environment. In the first 18 months, only 21 applications were received and 15 awards made, but it has been a general experience that all such schemes take time to gather momentum. The Medical Research Council is introducing a similar scheme for its own establishments in 1984.

2.19 To assist in promoting the schemes outlined above, particularly with smaller and medium-sized companies, SERC has appointed some Regional Brokers on an experimental basis. Their function is to introduce the help that 'local' universities and polytechnics in the region can provide with research, technical services and training through SERC schemes. The four Brokers operating in the South-West, South-East, North-East and Eastern regions have made contact with over 600 companies in the last two years.

The British Technology Group (BTG)

2.20 The BTG was formed in 1981 by merging the operations and management of the National Enterprise Board and the National Research Development Corporation. A major role of BTG is to undertake the commercial exploitation of academic inventions. Under the Development of Inventions Act 1967, BTG is required to balance its books, and therefore has to take a view on the probability of successfully licensing any inventions taken on.

2.21 Academic researchers are normally free, subject to the terms of their funding, to offer inventions and ideas to BTG if they wish, in return for licensing fees and funding. Where, however, work has been funded by one of the Research Councils, there is an obligation for the inventor to give BTG right of first refusal for his invention. BTG can provide the inventor with technical and commercial assessments, expertise in patenting and licensing, development and other project funding, and revenue-sharing arrangements. BTG also acts as a channel by which firms can be kept informed of academic inventions which are offered to it. BTG helps in setting up new companies itself to commercialise inventions from HEIs or elsewhere — this has occurred for computer software and biotechnology.

2.22 In the past 33 years, BTG and its predecessor have been offered over 20,000 inventions from public sector sources (about half the academic inventions were offered voluntarily), of which 7,000 were accepted for commercialisation. Over 1000 have been revenue-earning; about 30 have each earned more than £100,000, several over £1M, and one over £100M.

Charitable foundations

2.23 Several charitable foundations provide funds to encourage the application of HEI research to industry. Pre-eminent among these is the Wolfson Foundation which, over the period 1976-80, provided a total of

£6.2M to 29 academic institutions for university research with application to industry. Much of this was used to establish units within universities to undertake industrially-oriented work. Since the Foundation's activity started in 1968, 124 projects have been selected for funding; many of the units have become self-financing and have continued to thrive after the expiry of their grant.

Other measures

2.24 There are numerous ad hoc measures started at various times by interested parties. In addition, two competitions which are of relevance have recently been launched. The BTG's *Academic Enterprise Competition* was designed to encourage academics who were involved with establishing companies to commercialise their inventions. The £230,000 prize money in 1981 was distributed to 12 winners. The *Education in Partnership with Industry or Commerce* (EPIC) awards, sponsored by the Department of Industry, distribute about £60,000 pa to those HEI teams which can demonstrate the most successful partnership with industry.

3. Analysis and discussion

3.1 A summary of the written evidence we received is at Annex 1. In this chapter we present our interpretation of that and the evidence we received through interviews with individuals; and we offer some guidelines and examples of practice which industry and higher education institutions may find helpful.

Objectives and preoccupations of firms and higher education institutions

3.2 Higher education institutions (HEIs) are much concerned with the activities typically summarised in the charter of a university: the accumulation, interpretation and transmission of knowledge. 'Transmission' is generally taken to mean teaching and the exchange of research results with other researchers through conferences and publication in learned journals and books. This interpretation may be contrasted with the typical 'mission' of French researchers, established by statute, which is defined as the development of knowledge, its transfer to industry and society, its popularisation and administration, and the education of young and old. The French definition represents a wider formal interpretation of the 'transmission of knowledge' than applies in the UK. On the other hand, the objective of industrial companies is to create wealth and foster the required innovation. These objectives (of HEIs and industry) were not adopted or designed to be complementary, and the 'natural' degree of alignment between them is small. But such alignment of objectives is acknowledged to be productive, and the evidence we have received suggests that if it could be increased, and the mechanisms for interaction better defined, there would be benefits to both sides.

3.3 There is clearly a good deal of interaction between higher education and industry, but performance is variable. There are some examples of excellent interaction and others of indifference. There are, in addition, differences between different sectors of industry and between academic disciplines. Some companies in the electronics, pharmaceutical and chemical industries —

particularly the larger companies — claim to have closer and more extensive links with HEIs than other sectors of industry. This may arise because the companies have substantial research and development programmes of their own, including work with a long timescale, and are well-placed to collaborate with HEIs as equal partners. Some smaller firms, particularly in electronics, also have good links through taking up commercially some of the more specialised products or services originated by HEIs; the instrumentation field offers many examples.

3.4 All companies can potentially draw upon a worldwide base of academic knowledge and expertise, and larger firms will be able to seek out the best, wherever it may be found. However, companies frequently find it easier to collaborate with HEIs in the country and the region where they have their own industrial research facilities and from which they recruit their graduate staff, and industrialists in the larger firms informed us that the environment for such collaboration is as good in the UK as anywhere in the world. It is clear, though, that more needs to be done to persuade a wider range of firms to benefit from this environment.

3.5 Attitudes play a crucial part in determining progress with HEI-industry relations. While some firms and HEIs providing evidence to us did criticise the other party, about a third of respondents to our enquiries were genuinely self-critical. Firms were, though, not particularly hopeful that much more could be done to increase the overlap between their interests and those of HEIs, although nearly all agreed that links between industry and HEIs were a good thing and no respondent felt that there should be less contact between HEIs and industry.

3.6 We feel there are several reasons for firms' pessimistic view. First, industrial managements — if they are familiar with HEIs at all, and many (especially in smaller firms) are not — will remember them as establishments which taught them some years ago, or currently teach their sons, daughters or junior staff. HEIs are not, for many firms, obvious research contractors nor (according to memories) are individual academics. Secondly, bad news travels faster than good, not least because firms will tend to keep quiet about any academic goldmines they find (though they are ready to complain publicly about failures), and academics may well be reticent about publicising their industrial work in case of disapproval from their peers. Lack of appreciation of the potential value of academic contacts is consistent with the Finniston Report's view of the level of technological literacy and general education among industrialists — the UK comparing badly with Europe, and Europe with Japan.

3.7 In contrast to industry, HEIs were more hopeful that problems involved in industry-HEI co-operation could be overcome. In part, HEIs are looking for external funds to make up for the cuts in funds administered by the University Grants Committee (UGC). But there is a genuine feeling on the part of some HEIs that industrial exposure informs teaching (with benefits to the students) and provides a worthwhile outlet for research work which is an alternative to papers in learned journals.

3.8 Some academics, however, have fears about collaborative work. They think, first, that the free exchange of knowledge will be impeded by commercial confidentiality. We feel it reasonable that the provider of funds should control the publication of results that might directly affect his commercial interests, but in many industries the normal delays in academic publication provide adequate safeguards. Secondly, some academics fear that the balance between basic and applied research will be swung too much towards the latter. This could come as much, for example, from large numbers of SERC CASE awards as from direct industrial work. This is a risk, but we consider it a distant one in most HEIs where the current emphasis is the other way. Indeed, many firms — particularly the larger ones who make the greatest financial contributions to HEIs — emphasised to us the importance of maintaining the long term capability of HEIs to undertake top quality fundamental research. Thirdly, some academic staff have reservations about individual industrial companies benefitting commercially from publicly-funded research. The National Research Development Corporation was established partly to meet this concern but has not gained the respect of firms and HEIs. In our view, the return to the nation for its involvement in publicly funded research comes from the taxes paid by successful enterprises (and their employees) exploiting academic inventions, and from the employment which such enterprises create. Finally, some academics believe that their principal duty is towards scholarship and intellectual enquiry which has little in common with the concerns of industry. Such attitudes, where they exist, reflect the way in which industry and the academic world have failed to come together in the UK compared, for example, with the United States.

3.9 In the past few years there has been an awakening in the academic world that industry matters to them, and many academics and HEIs are setting out to see how problems can be solved and work undertaken in partnership with industry. Indeed many more HEIs are looking towards partnerships with industry as a significant and valuable part of their work. We hope that industry will respond in an equally constructive way. Informed experience is the best teacher in these matters — 'informed' in the sense that each party must understand the primary motivation of the other and must expect to have to work at the partnership if it is to be successful. The links established by third parties can help promote greater mutual understanding. These include particularly the SERC schemes, marketing or broking arrangements, and contacts established through teaching.

Links involving third parties

3.10 In Chapter 2, we outlined the various schemes which foster contact between industry and HEIs, either directly or as a by-product. We consider that there is scope for rationalising them. The schemes sponsored by the SERC are valuable, but there is a discontinuity between them and the measures to support industrial innovation promoted by the Department of Industry (DOI). This seems to arise from differing objectives. SERC supports good science, while, in some areas, favouring work with industrial relevance; DOI supports industrial innovation. In practice, DOI aims to support R & D done by those who will exploit it, that is companies themselves, whereas SERC can only provide direct support for HEIs, and these cannot usually exploit the results of research commercially. This difference of operation is, we feel, incompatible with the existence of the spectrum of HEI-industry partnerships which third parties should do their utmost to foster and which will require a corresponding flexibility in funding and exploitation arrangements. Set-piece schemes based on differing underlying philosophies may well not be the best way forward. DOI and SERC must come closer together to remedy this and in Chapter 4 we make recommendations to this end.

3.11 Formal academic-industrial liaison arrangements are established in nearly all HEIs, but seem to vary in their effectiveness. Industrial liaison officers must be of high calibre if they are to be acceptable to industry and must receive support, esteem and co-operation within their HEI. We would see them fulfilling three functions: to market the HEI's capabilities, to act as 'facilitators' in the conduct of HEI-industry activities, and to pull together the necessary ingredients within the HEI. But — like good parents — they should be aware of the need for changing relationships and not strive to keep others dependent on them. It defeats their purpose if they are anything but a catalyst or transparent interface: any attempt at monopoly or excessive profit-taking for their own purposes will deter rather than encourage co-operation. Furthermore, unless the institution is squarely behind its industrial liaison effort, any fall-off in business may well be met by retrenchment rather than more aggressive selling. Where contributing to industrial success is a clearly-stated objective of the institution, the situation is healthier and more stable. Without a clear objective of this kind, the tension between scholarship and utility appears more of a problem than it really is.

3.12 We have been told that academic industrial liaison officers do pass on to counterparts in other institutions industrial enquiries which they cannot deal with themselves. Apart from this, the only wider broking scheme is that operated experimentally by the SERC with high calibre brokers who are demonstrating the need and effect of such a service. There is a need for an effective national information and signposting service, using a computerised database, to let firms know where particular academic expertise could be found. We welcome the pilot scheme being developed at Manchester for the DOI, and other similar schemes. Smaller firms who might benefit most from, yet know least about academic advice or consultation are in the greatest need of help. There could be scope for providing this through the DOI's small firms information service, but the efforts of all agencies must be co-ordinated if confusion and waste are to be avoided.

3.13 A parallel type of broker operates in a more entrepreneurial way, becoming financially involved in the HEI-industry venture and usually taking a management interest. BTG (NRDC) and Technical Development Capital Ltd (a subsidiary of Finance for Industry plc) are two examples. Others include those involved in new enterprise projects, eg the Industrial and Commercial Finance Corporation or the Scottish Development Agency, who have respectively taken an interest in the property and management of different science parks. The DOI has also provided selective financial assistance for some of these ventures.

3.14 Research Associations (RAs) and independent contract research organisations (CROs) see a role for themselves in bridging the gap between academic research and the firms which they serve. Their performance in this respect varies very widely. HEI research is usually discipline-based whereas many RAs are based on industry sectors. RAs and CROs may be able to act as the agents by which HEI work can be selected and adapted for use in industry sectors.

3.15 HEIs are seen by some research organisations as publicly-subsidised competitors. We are aware that some HEIs do charge less than full economic cost for their services. They should not do so unless there are special academic reasons for charging on a marginal basis, for HEIs may be prejudicing the quality of their scholarship if funds intended for that purpose are used to subsidise work for industry. In terms of contract work, provided HEIs do not unfairly undercut the research organisations, we see no reason why they should not exist in competition with one another.

3.16 Within many HEIs, there are autonomous units, institutes, or wholly-owned companies (many established with Wolfson Foundation aid) which exist to serve particular departments or the whole institution for industrial work. We see a need to identify clearly the role which these organisations play. Their job of disseminating information and awareness should not be compromised by an over-riding urge for commercial success at any price. They can engage in cross-disciplinary work, more difficult to organise within academic departments; they are decoupled from traditional academic timescales; and they can act as staging posts for academics and industrialists who are interested in the work of the other sector. We commend them to HEIs as useful means of working with industry.

Mobility

3.17 The best method of technology transfer is held to be people transfer. The same is true of spreading understanding and awareness of other subjects. For example, people who have worked for a time in either the higher education or the industry sector before moving to the other tend to have a greater appreciation of the interdependence of the two than those who have had a single career path. In addition, the methods and disciplines of one sector can benefit the other.

3.18 A major impediment to transfer between employers is the different treatment of employees who move by different pension schemes. In some cases the mobile pay a heavy penalty while, in others, there is none. A member of the University Superannuation Scheme (USS) moving to another employment in the public sector will be able to take his full pension rights with him. A move from HEI to the private sector will usually be more complicated. In some cases he will be able to transfer his pension rights to his new employer's scheme with little or no loss; in others he will have to leave them in the USS, to provide him with a preserved pension on reaching the USS retirement age. (This preserved pension will be revalued in line with inflation). Greater problems are likely for people moving from a private sector employer into HEI employment (or indeed from one private sector employer to another). Some employers do not pay transfer values; and while in this case they must preserve the leaver's pension entitlement in their own scheme, they are under no obligation to revalue it to take account of inflation. In short, in many cases mobile employees will suffer a loss of pension rights as compared with stayers. The Occupation Pensions Board have already proposed remedies and we hope these will be implemented soon: they would help to foster further interchange between industry and HEIs.

3.19 Short term transfers, ie secondments or part-time appointments, are more difficult to arrange where there is no tradition of them, particularly when times are hard. The best people are too valuable to lose, even temporarily, and guaranteed return tickets are increasingly hard to come by. We are aware of the historical origins of academic tenure, in the sense of lifelong entitlement to a particular job. In science and engineering, where knowledge advances rapidly, it is essential that opportunities are offered to tenured staff to re-train and gain new experience. The need for re-training and varied experience has long been recognised in industry, where mobility within a firm, and between firms, is very much greater. We would therefore argue for greater flexibility in the conditions of employment of academics to enable them to obtain easier secondments or part time employment, for improved management within HEIs to facilitate transfers and for greater industrial awareness on the part of teachers and researchers. The following suggestions represent possible arrangements for new memberts of staff—

— more flexibility for academics to concentrate on particular types of activity, whether traditional teaching, research and administration or work for industry;

— industrial experience as a condition of appointment to a tenured post in industrially-oriented departments;

— contracts of employment of indefinite duration but with 3 or 6 months notice on either side, as tends to be the case in industrial companies;

— more untenured short term (5 year) appointments at higher pay to make up for lack of security and perhaps with a gratuity at the end of the term;

— the buying-in of more teaching staff from industry and commerce (for example, in medicine and architecture, teachers are frequently practitioners);

— the option for academics to work part-time outside the HEI, for example in their own enterprises, without breaking their HEI links. For example, an academic might give his institution an equity share in his business in exchange for the right of return to the HEI should the business fail;

— more joint appointments; for example, integrated chairs on the Salford University model, whereby an individual has substantial professional responsibilities in the university at the same time as exercising a senior managerial role in a firm or other corporate body. One of the main benefits envisaged is the generation of joint programmes of research and development;

— the appointment of industrialists to temporary senior posts in HEIs, topping up their HEI salaries as appropriate.

Such measures would increase diversity in types of appointment and job.

Incentives and disincentives

3.20 There are other disincentives to university-HEI interaction. Some in industry may see it as a loss of face to go to an HEI for help by way of contract or consultancy. Their employers may in addition feel that they are paid to solve problems themselves, not to incur extra expenditure by involving others. This is less significant for large firms who are in a position to regard HEIs as an extension of their own innovative research capability. But, whatever the size of firm, the 'not invented here' syndrome is powerful and the cure may involve difficulties which top management alone has the power to overcome. Good HEI-industry interaction is dependent on explicit support by top management.

3.21 For academics, there are significant disincentives to industrial involvement (although there are, of course, notable exceptions who have not been deterred by them). In the past, HEIs who gained significant income from non-exchequer sources were liable to have their recurrent grants cut in proportion. This, we suspect, arose from misguided notions of 'fairness' whereby the successful were held back so as to help the weaker. This practice penalised those who demonstrated excellence which private funding bodies — whether firms or foundations — were prepared to support financially. In our view, excellence should be built upon, not constrained to zero growth, and initiatives encouraged which lead to the strengthening of high quality work, in particular that which is valued outside traditional academic peer groups. We therefore applaud the firm undertaking of the UGC not to cut universities' grants if they obtain outside finance, and we would argue that they should increase support to those whose standing has thus been demonstrated.

3.22 The primary basis for assessing academic promotions has in the past been the quality (and number) of publications. But this is only one criterion. Another is the willingness of industry to pay for the services of the academic. In the arts, where output other than papers is limited, the traditional basis may be the only reasonable one. But in some areas of science, and in engineering, it is entirely possible for excellent work of timeliness and promise to result not in a publication in a learned journal but in a patent or an artefact which makes a significant contribution to the industrial economy. It is therefore problematical whether all academics should be judged on a common base (publications) which ignores some factors, or whether alternative promotion routes should be available. We feel that industrial work should be taken into account in academic promotions. In addition, industrially-oriented academics should be able to benefit personally from their industrial work — even if this gives rise to parallel breeds of wealthy lecturers and impecunious (but academically esteemed) professors; those of the highest abilities, of course, may achieve both wealth and fame.

3.23 In terms of cash rewards, academics who undertake private consultancy work outside their institution generally retain their earnings — subject to any charge for the use of institutional facilities. We suggest to HEIs that academics should be enabled and encouraged to carry out practice outside the HEI in parallel with their duties within the HEI. This benefits both sides, and increases the quality and effectiveness of teaching. This applies widely in the United States where the reputation of a teacher and researcher depends substantially on his ability to hold his own as a professional practitioner. In the USA, 50 days per year is the norm for consultancy and a survey in 1969 showed that 40% of all US academics (65% for engineers) then undertook paid consultancies. The figures are now believed to be much higher. We feel this level of effort is justified by the benefits, though higher levels might affect HEI duties to the point where the academic should seek to reduce this HEI employment to a part-time basis.

3.24 Consultancy should be regarded as the seedcorn from which more substantial university-industry links grow. A recent survey in the USA of a large number of collaborative projects found that three-quarters grew from previous consultancies. HEI administrations must ensure that the tensions between contracts to the university (which include overheads) and individual consultancies (based on private profit) do not cause the latter to be stifled.

3.25 Various arrangements apply to the licensing revenue received by HEIs from the BTG. We are attracted by methods which divide BTG receipts between the academic inventor, his department and the HEI's research fund. The latter is then distributed at the discretion of the Research Committee, a body already existing in certain universities and advocated for all in the Merrison report 'Support of University Scientific Research' (Cmnd 8567, 1982).

3.26 A few HEIs adopt a resolutely neutral attitude to industrial interaction and exploitation by their staff. This is coupled, in some cases, with contracts of employment which neither encourage nor unduly restrict external professional activity by academics. While the onus is on individuals to show initiative, institutions should be supportive: resolute neutrality may have a negative effect on industrially-oriented academics who feel in need of reassurance from the institution that what they are doing is proper and worthwhile.

New firms

3.27 The encouragement of academics to start up their own companies is generally outside HEI's arrangements for industrial liaison. Small firms of academic origin have the same need for financial and advisory services as other small firms. Experience in a big firm is not a fully adequate substitute for familiarity with a successful small business. We suggest that the DOI take steps to ensure that academics are fully aware of the advice and support available to small businessmen. Spinning off firms from HEIs, especially in fast growing high technology areas, can permit flexible employment opportunities for academics, quite apart from the obvious financial benefits. Success breeds success by example, and it is noticeable that in several locations a few good business starts encourage others. Some universities eg, Loughborough, provide appropriate 'project support' for new ventures, and this or similar services should be expanded. The DOI Small Firms Service can help here.

3.28 In the Cambridge area, there has been a very marked growth in small, high technology firms, particularly in the computing and electronics sector. These have used very diverse premises generally within cycling distance of the colleges, and have certainly not been confined to the Cambridge Science Park. The local management of Barclays Bank identified the trend at an early stage and appear to have played an important part in developing a special relationship with these companies. It is the closest parallel that we found to the 'Route 128' developments surrounding the Massachusetts Institute of Technology and there is no reason why it cannot be replicated elsewhere in the UK. A published study of the 'Cambridge phenomenon', bringing out the examples of good practice by university staff, postgraduate students, bankers and others could be of great benefit and we hope that an agency concerned with innovation will commission it.

3.29 There has been much popular interest in science parks which are seen as vehicles for academic-industrial interaction of a kind which could bring national and local economic benefits. They appear to provide the opportunity for small firms to start in low cost accommodation (with the possibility of sharing some common services) and close enough to an HEI for ready interation between industrial and academic staff, to the benefit of both. The extent to which science parks in the UK conform to this image was considered in the report 'Helping small firms start up and grow' (HMSO, 1982) prepared by Job Creation Ltd for Shell (UK) Ltd and DOI. Our own view of science parks largely supports that report, and we outline the main elements below.

3.30 We consider individually the aspects of the popular view of science parks. First, the parks do provide accommodation for small firms. But these are more likely to be growing enterprises than start-up companies. The latter seem to prefer 'garage' type premises in the early days or small (500-1000 sq ft) 'incubator' accommodation which may or may not be located on the science park. Second, some science parks offer landscaped, low density premises with correspondingly premium rents — this has tended to be the US model. The UK parks do, however, include lower cost premises with lower specifications. There are also both high and low cost examples of incubator schemes in the UK; the cheaper ones with lower specifications seem to have attracted more tenants, but some new high technology firms may need prestige premises in keeping with the high value of their products and to attract high quality recruits. In this respect, expensive premises may be cost-effective in management terms. Science parks are seen as providing common services, but these are more commonly provided to the tenants of incubator accommodation than to other tenants on science parks. Again, the lower cost services are most used, and some firms prefer to arrange their own office support. A further common service might consist of financial and business advice of which (as we said above) small firms have a particular need. Finally, proximity to an HEI is not a sufficient condition for interaction between the institution and firms on the science park. This needs to be actively managed. We note elsewhere in this report that both parties need to work at academic industrial collaboration, so as to ensure that HEI expertise and facilities are made available to firms and that firms contribute to HEI research and teaching.

3.31 As the report by Job Creation Ltd emphasises, effective management of science parks is the key ingredient for their success in establishing HEI-industry links. This involves consideration of the kind of tenants for which the park should be designed, how to attract them, and how the HEI should interact with them. Professional management expertise is likely to be required. A second important ingredient concerns marketing — market research before the scheme starts, and continuous marketing of the scheme once in operation, both to potential tenants and within the HEI.

3.32 It is too early to make a final judgement about the success of ventures such as science parks in the UK. Where all the right ingredients are present, we see no reason why they should not succeed as means for academic-industrial collaboration and for the establishment of new firms. These ventures are, however, relatively slow developing and need a reasonable time (up to 10 years) in which to prove themselves. Local authorities and the institutions providing finance will need to have this in mind and should not seek an early return on their investment through, for example, the early reversion of unoccupied science park accommodation to office use. We would urge that, where ventures are in place or being planned, those concerned should consider them in the light of our comments, and establish clearly the objectives of the venture and the means of achieving them.

Students

3.33 Teaching and students provide means of communication between HEIs and firms, as well as of productive co-operation. HEI teachers who have awareness of industry and business acumen are likely to help students to fit more quickly into an industrial and commercial environment, while students, particularly those on sandwich courses, provide a route by which industrial concerns become known to the HEI. A model is provided by medical schools — indeed by the whole concept of the teaching hospital where the teachers are themselves practitioners and teaching is intimately connected with practice. The SERC/DOI Teaching Company scheme is modelled on this medical analogue.

3.34 Short courses and seminars have, as a useful by-product, the creation of contacts between industrialists and academics, but there must be a readiness on the part of teachers and participants to talk to each other about problems and remedies. Sustained contacts may well be more effective than the casual contacts derived from short course teaching and we were attracted by the new Integrated Graduate Development course being run at Warwick University in conjunction with British Leyland, Rolls Royce and Lucas. This teaches new graduate entrants to these companies to Masters level and includes a 4-month project within the parent company, which is jointly supervised by an academic and an industrial supervisor. For many applied subjects, this model would seem preferable to the traditional, academic MSc and we hope that funding agencies such as SERC, in consultation with the Engineering Council, will assess its value and give it appropriate priority in future.

3.35 We are also attracted to the arrangements in the West German technical universities whereby industrial companies suggest PhD projects — often to be undertaken by their own employees — to academics with an appropriate interest. The Fraunhofer institutes in particular supply industrially oriented environments in which PhD work can be done. In the UK, SERC's CASE awards already permit the industrial specification of projects, and the CNAA and certain universities award external PhDs. We suggest that SERC should opt for more industrial orientation in its postgraduate training especially in engineering subjects. A PhD provides training in research disciplines, as well as a means by which knowledge is generated. Other things being equal, we would wish the knowledge to be applied sooner rather than later — hence the industrial specification of projects. In addition, we feel more opportunities should be given for part-time PhD work, which represents a good return in terms of training and industrial partnership at little outlay.

3.36 Sandwich courses are valuable as an undergraduate training mechanism, with the side benefits of making HEI — industry contacts and broadening the industrial awareness of teacher and student. Public spending cuts have recently resulted in fewer sandwich courses in HEIs, and firms, finding themselves under financial pressure, have found it increasingly difficult to provide placements during the industrial phases of sandwich courses. We are concerned at those trends, both of which serve to reduce HEI — industry contact. Part time post-graduate courses are also a direct way of feeding academic experience to those already working in industry but the public funding available is negligible compared with that spent on full-time courses.

Special factors affecting polytechnics

3.37 Nearly all of what we say about HEIs affects both universities *and* polytechnics. But there is a special factor affecting polytechnics which universities do not experience: the overseeing power of local authorities. By statute, local authorities have power over all polytechnic staff appointments and promotions; they are the legal entities which sign contracts affecting the polytechnic, and they have a right to all cash receipts. It must be said that many authorities commendably delegate these powers to the polytechnic governors and administration so that the polytechnic has almost as much autonomy as a university, but some do not. This greatly inhibits those polytechnics' freedom of action in working with and for industry.

3.38 We understand that polytechnics and polytechnic teachers because of their local authority base — are in an ambiguous legal position in undertaking work which is thought not to relate to their primary (teaching) function. Work of assistance to industry might be considered to be in this category. This problem, and the influence of local authorities, can conspire to make polytechnic-industry links difficult if the local authorities do not take an enlightened attitude. Furthermore, while the universities have a notional provision of funds for research additional to that for teaching, the polytechnics have none. We feel that these factors work directly against the Government's original principle that 'it will be necessary to make the provision for research (in polytechnics) which is essential to the proper fulfilment of their teaching functions and the maintenance . . . of close links with industry . . . so as to promote the rapid application of the results of research to its problems' (circular AM 8/67, DES, 1967).

Practical problems in academic work for industry

3.39 Much was said to us about the different *timescales* on which academics and industrialists work. Part of the difficulty arises from the different purposes of academic and industrial enquiry: academics seek rigorous, intellectually satisfactory understanding of problems, while industrialists need solutions to problems sufficient only to get their product or process to the market. These aims are not necessarily mutually exclusive. Some aspects of industrial work require rigorous solution in order to understand product or process parameters. Furthermore, if academics and industrialists each understand the natural inclinations of the other and the work in prospect carries real mutual benefits, an accommodation can nearly always be found. The most satisfactory arrangement is a jointly arranged programme of work (in which both firm and HEI can participate) which meets the long term interests of both sides, and satisfies the more immediate needs of the firms as well. This takes good will on both sides, and we would wish to see more firms willing to try this approach.

3.40 There may also be some difficulty in relating an industrial problem to the academic calendar. The natural academic periods are those of a one or three year postgraduate course, or a few days consultancy. In addition, non-urgent, lower level work might be taken up as student projects. The difficulty arises where a company thinks a job will last six months and wants it started fairly quickly. This is where HEI-owned companies or industrial units score. Their staff are decoupled from the traditional academic timescales, being as free to take up work as any contract research organisation but benefitting from close contact with academic research groups. Relatively short term work of this kind can only be done well if it is underpinned by a core of high quality research work which both helps to provide answers to industrial problems and may lead to questions about the basis of industrial technology. It must be noted that such units are not a substitute for a top-line research group doing high quality research, but complement them by, for example, facilitating multidisciplinary work.

3.41 The commercial *confidentiality* of industrial research when carried out in an academic environment was also held by some contributors to be a problem. Again, provided academic and industrialist understand the aims of the other (typically, the academic to publish, the industrialist to remain ahead of the competition) this need not be a difficulty. But there are variations with industry sector and academic discipline. For example, the pharmaceutical industry depends heavily on proprietary products, and confidentiality at the research stage is crucial. But in engineering, success depends more on the effective use of technology than proprietary rights to it. The publication of work fully funded by industry must be understood from the outset to be at the discretion of the firm, but publication may well be useful free advertising for a new product or process. On the other hand, acceptance of confidentiality need not prevent the work of academics coming to the notice of their peers, because the output of a research group — even if unpublished and not directly attributed — may well be recognisable to the cognoscenti. Furthermore, to see their work used may in itself be an alternative reward for some academics, especially engineers. Young academic scientists seeking to make their mark may be inhibited in not being able to publish quickly, but equally scientists in industry have to compromise between professional peer recognition and the confidentiality which is likely to be a condition of their employment. We hope that, in the academic environment, confidentiality will become less of a problem when industrial work is more generally accepted as a criterion of worth, as discussed in paragraph 3.22.

3.42 A related matter is *patenting* (and consequential *licensing*) versus publication. Firms may well require patent cover before they take up an academic invention, or wish to have a right to intellectual property generated by work which they have funded (in whole or part). Most of the difficulties that have arisen in the past arose principally because arrangements were inadequately formalised: people did not know where they stood. The essential steps are to negotiate, to agree, and to put in writing (before work starts) the agreement covering patents, rights, royalties etc even if the need for such agreement appears unlikely at the outset. The Committee of Vice Chancellors and Principals issued in 1979 a report by a working party on patents and the commercial exploitation of research results which sets out further guidance on these essential steps.

Intellectual property rights, know-how and the British Technology Group

3.43 At present, the BTG has the right of first refusal on inventions arising from work funded by a Research Council. This does not stimulate HEIs to take responsibility for exploitation, though academics feel free to criticise BTG roundly if exploitation is not achieved even if for sound business reasons. As a consequence, the BTG and its predecessor NRDC have been widely criticised as inefficient and rapacious, an obstacle to industry-HEI co-operation and a barrier to the exploitation of academic inventions. Our view accords with the ACARD report 'Exploiting Invention' that BTG's right of first refusal should cease. Many complaints would lose much of their force if BTG were no longer monopolistic.

3.44 The trade in intellectual property capable of legal protection (by patent or copyright) has hitherto been over-emphasised at the expense of trade in know-how, although there are variations between sectors. A considerable (and perhaps increasing) amount of research output is not readily patentable, and is best exploited in exclusive deals between the HEI and a firm. BTG has in the past gone for patentability, and the lapse of its right of first refusal would encourage greater exchange of know-how between HEIs and industry. Such increased exchange is to be encouraged since much process technology has traditionally not been proprietary, success coming to the firms who made best use of generally available knowledge.

4 Conclusions and recommendations

Introduction

4.1 We are convinced that the overlap of interest between industry and higher education institutions (HEIs) is productive, and that benefits would accrue to both sides by increasing the area of overlap. Industry (of all forms) survives only by innovation. This entails a long-term view of a continuous and evolving chain from research to exploitation, requiring both intellectual and practical skills at every stage. Industry and HEIs between them can muster these elements. Indeed they must do so, to make the best of the UK's science and technology. Some of the most rapidly advancing industries have already seized the opportunity.

4.2 Previous chapters have shown the extent to which Government is involved in the creation and maintenance of HEI-industry links — through its financing to university research, its support of Research Council schemes, its responsibility for the BTG etc. It follows that Government policies towards such links, and the research which is the reason for their existence, should have a similarly long-term perspective. The creation of scientific knowledge in HEIs, and its application through engineering in the industrial economy, is too important to our national well-being to be the subject of short term political fashion or financial expediency. We would liken this to national defence, which enjoys significant political and financial continuity. With the long-term importance of the subject in mind, we see four principal themes as providing the key to progress.

Principal themes

4.3 HEIs differ one from another, each being excellent in particular subject areas or ways of working. We consider that such *differentiation* should be encouraged more than it is at present, building on excellent features of each HEI. In our view, HEIs themselves should be given sufficient financial flexibility to follow their chosen path of development. The aim would be to strengthen quality — whether of basic research, applied research, or teaching.

4.4 We have no desire to undermine excellent research and scholarship of any kind. Many of the fundamental investigations carried out in HEI departments in the UK are of the highest intrinsic merit and this work should continue. Moreover, much apparently speculative research subsequently reveals the germs of important applications. But it must be admitted that some work may be of less urgency, importance and even interest. Such work, in our view, has pre-empted resources which might otherwise have been devoted to industrially-oriented activities by researchers willing and able to carry them out. Reductions in public spending have left HEIs with fewer staff and, unless teaching methods are adapted accordingly, the increased teaching burden will further pre-empt research resources. It is not in our remit to advise on HEI teaching methods; we are considering the factors which encourage or inhibit research links between HEIs and industry. In this connection, we see the need for a more balanced allocation of research resources within HEIs by enabling researchers who wish to do so to undertake more industrially-oriented work. This will encourage others to move their talents into areas of research which are both academically worthwhile and have a ready industrial relevance. We envisage such work as being of strategic value to industry, not simply solving immediate problems. In summary, *HEIs need to reallocate research resources* away from worked-out areas of research towards areas that retain potential for further advance and are likely to benefit from the stimulus of applied research allied to them. Research and teaching carried out in partnership with industry can be just as challenging and rewarding as traditionally more academic activities, and indeed is often more difficult. Moreover, it can expose deficiencies in basic understanding and point the way to further fundamental research.

4.5 There must be a corresponding change in the practice and attitudes of industrial companies towards collaboration with HEIs. Universities and polytechnics in the UK have knowledge and expertise which can strengthen existing enterprise and generate new business ventures. Foreign firms are well aware of this, and are taking advantage of it. There must therefore be commensurate *industrial initiative* from British firms alongside the reallocation of academic research effort and increasing differentiation of HEIs. This implies a willingness on the part of industrialists to explore with academics the exploitable research available in HEIs, and to consider what further work they might do in partnership to the benefit (financial and otherwise) or both.

4.6 The *Government, with public sector bodies, also has an active role* to play. It should actively promote partnerships between HEIs and industry, both by providing financial incentives to each partner and by organising itself in a way which facilitates co-operation. Furthermore, Government departments and agencies should set an example by paying attention to the interests of their academic partners when entering into partnerships with HEIs.

Responsibility for initiative

4.7 We are aware that our subject represents very well-trodden ground — the volume of literature is fearsome. But, accepting that some progress has been made, still more needs to be done by way of practical achievement. There has undoubtedly been an increasing realisation that industry and HEIs can work together for the benefit of both, but action has been slow in coming. The UK, with its excellent record of science and technology, has much to gain over its economic competitors if it can act coherently and effectively.

4.8 We are not assigning blame for poor past performance, although we do of course applaud past initiative. Instead, we have sought ways of making progress. We believe a pragmatic approach is needed, using whatever levers of influence exist. The strongest lever is money — to reward achievement and foster initiative — building upon excellence and encouraging the ordinary to become excellent. We have therefore paid more attention to HEIs, simply because their funding from public sources provides mechanisms for encouragement and reward. Moreover, HEIs have the privilege of considerable freedom of action, and it must be balanced by an equal degree of responsibility. It can be argued that they have a duty (like the French legal definition mentioned in paragraph 3.2) to disseminate the results of their work to all those in a wider society who might apply it, in a form which the recipients can understand.

4.9 This does not, of course, relieve industry of its responsibility to be intelligent, active and far-sighted in co-operating with HEIs. It is industry, as well as society at large, that will benefit from successful co-operation and those in industry must work for the respect and confidence of their academic partners. Companies have much to offer HEIs in terms of experienced people, advanced facilities and business acumen.

4.10 Both HEIs and industry still show a certain reluctance to get together. Our recommendations should assist towards recognition of far greater common interest between the two parties. But for the moment we need to give the responsibility for taking the initiative, with appropriate opportunity for reward, to one side. From the views expressed to us, and bearing in mind the examples of excellent practice which have been drawn to our attention, we conclude that it is HEIs which should mainly take the initiative in forging the links.

A principal conclusion is that the initiative in forging new and productive HEI-industry links should lie mainly with HEIs. Industry will need to match this initiative with a constructive response and initiative of its own.

4.11 The recommendations which follow will take different times to affect the problems identified in this report. In the light of previous reports on this subject and the lack of subsequent action, we suggest that actions be monitored for effectiveness, and the results reviewed after an initial three year period. Other corrective mechanisms may be suggested in this process.

Differentiation among HEIs and the re-allocation of research resources

4.12 The dual support system for university research was reviewed in the Merrison report 'Support of University Scientific Research' (Cmnd 8567, 1982). Two of the report's conclusions were that, as a longer term objective, universities should channel proportionately more of their funds into research, and that, to achieve high quality and proper support, research funds would need to be concentrated into selected areas. We endorse these conclusions. The report also recommended that universities should establish Research Committees to allocate within the institution the funds available for research. Some have done this. But we see a logical extension of these principles, which we now set out.

4.13 Our general view is that university-industry partnerships have not been well served by the dual support system in recent years because of the strains it has been under. The Merrison report discussed these in some detail. Partnerships would be encouraged by a differentiation of aims and purpose between the universities, and the development of research capabilities properly balanced as between the fundamental and that with a more ready industrial relevance, both being of similar quality and standing. The size and balance of research capabilities in particular institutions should be management questions for the universities themselves. This requires information to be available to the university administrations about the funding intended for research, and about the ways in which their resources are deployed. We have already remarked, in paragraph 4.4, that financial pressures on universities have been accommodated through reductions in research activities and have not led to a re-appraisal of teaching methods. This process has gone largely unmonitored and unmanaged. The Research Committees advocated in the Merrison report, with the management information outlined above, should monitor the effects of spending cuts on university research and take remedial action.

4.14 We recognise that it is difficult for academics to identify precisely the proportions of their time spent on research, teaching, administration etc. But we understand that estimates can be made for some departments in some institutions. There are, however, other elements of university expenditure which we consider can be apportioned — technician time, instrument use, materials etc; this should be done for management accounting purposes. Similar difficulties and opportunities would apply in identifying the research component within the UGC block grant to the universities. However, for the purposes of management within the universities, some indication should be given about the proportion of UGC funding which universities could expect to devote to research.

4.15 Despite the difficulties of identifying the proportion of his time an individual spends on research, we feel that agreement is needed on the proportion of academic time which should be spent on research in the universities as a whole. Official statistics assume that on average 30% of the UGC grant is spent on research. This figure arose from an enquiry conducted in 1969/70 by the Committee of Vice-Chancellors and Principals (CVCP) into the use of academic staff time. The Merrison Report considered, however, that the fraction was now smaller and anecdotal evidence given to us strongly supports this belief. We consider such a divergence between theory and practice to be unacceptable. We believe, therefore, that the research component of UGC funding as a whole should be identified. A reasonable national average for the proportion of academic staff time spent on research might well be 30% — the proportion which was found in 1969/70. To encourage differentiation, each university should indicate to the UGC the proportion of funds that it wishes to devote to research; we believe that some universities may well decide upon a figure for academic staff time spent on research below 30%. The UGC should then undertake to allocate, as an identified component of its grants to universities, funds for research that take into account the chosen level of research activity and should then ensure that such funds are used for that purpose.

> ***A principal recommendation*** **is that DES, UGC, CVCP and other relevant bodies take action—**
>
> **a. to agree an appropriate average level of research activity in universities, each university proposing the level which it wishes to adopt;**

b. to assure adequate support for research by means of an identified proportion of the UGC grant;

c. to ensure that funds intended for research are used for that purpose;

d. to ensure that research funds are effectively managed by universities by means of Research Committees (as advocated in the Merrison Report) or equivalent bodies.

4.16 We recognise that the pruning of block grants has caused difficulties in universities. But this pruning has forced a number of universities to address issues of resource management and accountability with a degree of vigour; this is a welcome and necessary trend. We are, though, concerned at the effect of the recent UGC cuts on the science and technology capability of HEIs, their ability to market their wares, and their ability to co-operate with industry. First, there is evidence that the cuts may have borne more heavily upon research in science and technology than had been intended. Since academic scientists and engineers tend to be more mobile than others, their ranks have been selectively depleted in those universities which met the cuts by leaving vacancies unfilled. Secondly, there is a tendency for financial stringency to result in retrenchment of marketing activity rather than in more aggressive marketing. HEIs have not in the past been good at selling themselves (to industry or indeed to society at large) and retrenchment is a step in the wrong direction. Thirdly, the increased teaching load following the cuts means less research time and less headroom for accommodating those co-operative activities which take time and effort to set up. Some financial headroom will be needed for HEIs to build upon their chosen excellences and move towards work of high quality and utility. In this connection, we applaud the UGC's commitment that recurrent grants to universities will not be abated because of university receipts from other sources.

4.17 We therefore see a need to provide extra funds to HEIs to provide more staff time for more industrially-oriented work, and to underpin it. This would help prevent talent being drawn away from the longer range work that is needed as the basis for future collaboration, and research time being further eroded by the demands of setting up and managing partnerships with industry. The best indicator of this need is the sum which HEIs earn from the private sector and the public trading sector through contracts, consultancies and investigations (earnings from teaching and training would be excluded). We envisage an *industrial seedcorn fund* being established amounting to 25% of HEI's industrial receipts (which are currently about £40M pa). DOI might contribute half of the fund, other industry-sponsoring departments about £1M each, and DES the balance. None of the contributions should come from within existing provision for HEI research. The fund would be divided among

HEIs in proportion to their industrial receipts. A code of practice should be provided to help HEI governing bodies to determine the wise use of such funding, based on the following principles—

i. the fund is intended to support the infrastructure and the basic research that will complement effective, externally-financed applied work; it must not be used to subsidise tenders for external work;

ii. it is to pay for staff and such items of equipment as are not covered by the UGC capital equipment fund or its polytechnic equivalent;

iii. HEIs should decide the balance between appropriate development of current work, and new expertise which may provide a basis for industrial work in the future; but, other things being equal, departments which earn industrial money should receive a pro rata share of the HEI's allocation from the fund;

iv. HEIs should control the use of their portions of the fund by means of research committees as recommended in the Merrison Report, and assure reasonable balance between short term and longer term applications;

v. inter-disciplinary working should be encouraged in order to meet increasing demands for such work from industry.

The target for eligible earnings would be £100M pa in 5 years' time. This should be seen against the present fraction of their grant and fee income which HEIs are thought to spend on research, and which amounts to about £400M pa. The allocations from the fund should be spread over rolling periods of 3 years to enable proper planning by HEIs. The SERC might administer this scheme, which would apply to universities and polytechnics, on behalf of the Government.

***A principal recommendation* is that the Government establish an 'industrial seedcorn fund' to support the infrastructure and the basic research that will complement effective, industrially-financed, applied research. The fund should equal 25% of the money earned by HEIs through contracts, consultancies and investigations from the private sector and the public trading sector (excluding contracts for teaching and training). This would initially require about £10M pa. HEIs should receive allocations from the fund equal to 25% of their eligible earnings. The fund should be established for 5 years in the first instance. Its size should be adjusted annually in order to remain equal to 25% of eligible HEI earnings.**

Further suggestions about the operation of this scheme are contained in Annex 3.

4.18 The preceding recommendation emphasises our primary purpose: to build upon success in industrial co-operation. But we recognise that measures will be needed to enable other HEIs, not at present much engaged in industrially-oriented research, to engage in partnerships with industry. We believe that modest pump-priming funds are needed to create the right infrastructure, and that DOI might appropriately provide them. In our view they should be allocated selectively, fostering the initiative of those prepared to reallocate research effort towards industrial collaboration. HEIs receiving substantial allocations from the *industrial seedcorn fund* would need a particularly strong case to justify pump-priming support as well. We consider these pump-priming funds might be best managed jointly by DOI and SERC. This pump-priming scheme would cover both universities and polytechnics. We would expect that any particular allocation from this fund would be for a limited period, on the assumption that it would result in industrial contracts which would attract allocations from the *industrial seedcorn fund.*

> ***A principal recommendation* is that a minimum of £5M pa be earmarked by DOI for an initial period of 5 years to be used for projects proposed by HEIs that contribute significantly to the infrastructure for academic-industrial co-operation. This scheme should be managed jointly by DOI and SERC.**

Examples of relevant projects might include additional industrial liaison posts in HEIs at senior level; the acquisition by HEIs of professional advice on legal, contract, patent and other business matters; the provision of management and marketing functions for ventures such as science parks and measures to promote mobility and interchange of staff with industry.

4.19 We would expect applicants for these pump-priming funds to demonstrate a serious intention and ability to make whatever changes might be needed in HEI administration to establish and build upon industrial contacts. In particular, we would see a willingness to redirect resources and to adopt a variety of flexible conditions of appointment — such as we set out in paragraph 3.19 — as evidence of serious intent.

> *We therefore recommend* that pump-priming funding be conditional upon evidence of serious intent by HEIs to adapt to industrially-oriented work, notably through appropriate conditions of academic appointments.

4.20 The relatively small sums of money recommended in paragraphs 4.17 and 4.18 do not reflect the volume of academic effort to be redirected; they are the means by which a substantial volume of academic effort may be redirected. The size of the *industrial seedcorn fund* reflects our assessment of the additional effort required to undertake collaborative work with industry, together with our estimate of the incentive required for HEIs to collaborate more.

4.21 Earlier in this chapter we endorsed selectivity and concentration in research as contributing to the support of excellence. Similar arguments can be applied in other spheres of academic activity, notably post-graduate training. We are not convinced that the Research Councils have done all that they might to apply to awards for post-graduate training the principles of selectivity which they apply to research grants.

> *We therefore recommend* that the Research Councils review their procedures for making post-graduate training awards in order to ensure that they contribute in the most effective way to concentration and selectivity in research.

Polytechnics

4.22 We are persuaded that over-detailed control by local authorities and the lack of central provision for research support inhibit industry-polytechnic interaction. First, although many local authorities take an enlightened view regarding their polytechnics, we feel that measures are needed to guarantee all polytechnics a sensible degree of autonomy and flexibility — without disturbing the delegated authority which many polytechnics already enjoy. But they should have it as of right, not by the grace and favour of the local authority.

4.23 Second, polytechnics are inhibited in their work for industry by the lack of any direct funding for research analogous to UGC research support of the universities. This is essential if polytechnics are to have the foundation and flexibility required for industrial work. We would emphasise, however, that as with universities, polytechnics should build only upon their particular strengths. They should not be encouraged to imitate the universities; nor should they aim at a research activity in every field. For this reason, we would not expect to see public funds used to build up centres of excellence in subjects already catered for adequately elsewhere or to create 'well-found' laboratories where these did not already exist. Third, the legal ambiguity about polytechnic work for industry needs to be resolved. Polytechnic research and consultancy should be a service which can be provided (and which polytechnics are encouraged to provide) to industry.

> *We therefore recommend* that the DES in consultation with DOE and other appropriate bodies take action to provide:

a. a clearer definition of the role of polytechnics with regard to research, notably that supportive of industrial contacts;

b. an identified amount for research activity, analogous to UGC support for universities;

c. an amendment of the law in order to allow polytechnics to negotiate contracts and undertake consultancies.

We emphasise that the financial measures proposed in paragraphs 4.17 and 4.18 would cover polytechnics as well as universities.

Industrial perspectives

4.24 It is essential that industry takes its own initiatives commensurate with those under way in HEIs. Industrialists must make themselves aware of the opportunities presented by work in HEIs, the potential for partnerships, and the constraints under which their academic partners would be working. It is our considered view that the work which HEIs undertake for firms (whether UK or foreign) gives them expertise and experience which firms in the United Kingdom are singularly well-placed to draw upon. If the academic resources put at the diposal of British industry are to be world-class, academics must be enabled to learn from worldwide industrial experience. Many academics expressed regret that much of their industrial work was for foreign companies. It is vital that British firms, in their own commercial interests, take up the opportunities offered by HEIs before their foreign competitors do. We have already remarked (in paragraph 3.3) that some of the larger companies recognise this and have extensive links with HEIs, at least in the disciplines traditionally of interest to them. But many other firms still need encouragement and help to establish such links, and the following paragraphs are addressed principally to them.

4.25 Personal contacts between top academics and industrialists are important in establishing collaboration between firms and HEIs. We see a spectrum of activities through which these contacts could be encouraged, particularly by the formation of clubs, analogous to the export clubs which have grown up in the UK, largely through the Chambers of Commerce and Industry. In these clubs, firms which export to a particular market share their experience with firms who do not. For HEI-industry links, we envisage a diversity in types of club. These might well be organised on a regional basis but would probably focus on a particular HEI, discipline or industry sector. Their activities would range from conferences and seminars to enable senior people to exchange information, views and cultures, to small consortia of technical people coming together to commission pre-competitive research projects with HEIs. A good deal of this sort of activity is already under way and its value should not be lightly dismissed by those in industry or HEIs who imagine that their own relationships with their counterparts could not be improved. Some of the most valuable associations of this nature may well be across disciplines, and these require effort and deliberation to cultivate.

> ***A principal recommendation*** **is that bodies on which industry is represented at a high level — CBI, BIM, NEDC, local Chambers of Commerce and Industry, the Fellowship of Engineering, the Royal Society and learned societies — should urge firms to show initiative commensurate with that of the HEIs in establishing and maintaining academic-industrial links, notably by bringing together firms with a common interest in a particular activity, discipline or HEI. Building upon what already exists, the Royal Society for the Encouragement of Arts, Manufactures and Commerce (RSA), with a membership and objectives highly relevant to this issue, should foster and co-ordinate these activities; the Royal Society of Edinburgh is well-placed to promote such activities in Scotland.**

4.26 Evidence suggests that it is a good investment of company time for senior staff to serve on academic and other committees — such as those of Research Councils. Members get to know, in a cost-effective way, both senior academics and their work, and can soon build up a set of front-line contacts through whom a wide range of others can be made. These would serve firms' immediate interests by way of research and manpower and help to increase the responsiveness of the higher education system generally. To follow up personal contacts, the technical directors of companies should have the task of obtaining information about academic capability and ensuring that academic industrial contacts are followed up. They should also encourage their less senior colleagues to become similarly involved. In this way firms should seek to have a 'mirror image' of the marketing work of HEIs.

> *We therefore recommend* that senior executives of industrial companies and their staffs should seek and accept appointments to bodies through which they can establish links with academics and learn of academic capabilities, and that they should actively follow up the academic contacts so established.

4.27 A number of particular steps can be taken to improve the directness of links between HEIs and industry, besides the greater staff flexibility advocated in Chapter 3. For example, we endorsed there the recommendation in ACARD's report 'Exploiting Invention' that BTG's right of first refusal to Research Council inventions should lapse. This was strongly supported by the evidence we received. Our view is that HEIs should be overtly and explicitly responsible and accountable for the exploitation arising from Research Council funding, and should retain the profits from exploitation. Indeed, we would go further and say that this responsibility should extend to all research funded by Government in HEIs unless the exploitation rights were explicitly withheld by the terms of the grant or contract. Innovation is a difficult process that in general works best with direct contact between inventors and those who seek to apply the inventions. The mandatory involvement of third parties can easily hinder it. The return to the public purse should be through the national benefits accruing from wealth creation rather than through a levy at the start of the innovation process. It is instructive to note that the USA has taken just this line recently in the legislation — the 1980 Bayh-Dole Act (Public Law 96-517) — which is described in Annex 2. HEIs should be enabled to exploit their inventions through British or foreign firms, although HEIs might be expected to offer inventions to UK firms first and to approach foreign companies only if no suitable UK firm was interested. As we mentioned in paragraph 4.24, academics regret that overseas companies are more willing than UK firms to collaborate with them, but we reiterate that UK firms must take their own initiative in establishing productive contacts with HEIs, for their own commercial benefits.

> *We therefore recommend* that HEIs should normally have the direct responsibility for ensuring that inventions are exploited. Any proceeds accruing to the institution, whether from royalty income or joint ventures or whatever, should remain with it and not be offset by any clawback arrangement, overt or covert.

4.28 We see two options for the future of that part of BTG which deals with the exploitation of inventions should its right of first refusal be revoked: to disband it, or to allow the market for its services to decide its future. We favour the second course of action. HEIs (and others) will continue to need professional services to ensure the exploitation of their inventions; BTG could provide some of these in the regions, on a fee-paying basis, operating no longer from a privileged position. The regional activity of BTG might sensibly be associated with the system of regional brokers which we discuss in paragraph 4.39.

4.29 We feel that the DOI is uniquely placed, through its technology support schemes, to encourage the involvement of HEIs in the applied research and development which it funds with industrial contractors. It already regards the cost of work subcontracted to HEIs as eligible for financial support under its sponsorship schemes. But it might, for example, provide an enhanced grant (say 50% instead of 33⅓%) to firms undertaking R & D in partnership with an HEI. This would not be aimed at coercing firms to commission extramurally R & D which would be better done in-house, but would make up for the uncertainty and extra management resources involved in a joint project and recognise the likelihood of further joint activities which might well not need public support. We are also attracted by the idea of a 'mirror image' of the SERC's Co-operative Grants Scheme. Under such a new arrangement, a firm wishing to sub-contract part of a research project to an HEI would be able to apply to DOI for a 33⅓% grant towards that element to be undertaken by the firm and 100% of that to be done by the HEI. (Under the Co-operative Grants Scheme, an HEI applies to SERC for about half the cost of a project to be undertaken in the HEI, with a company providing the balance; but the firm must bear the cost of any work it undertakes itself.)

We recommend that DOI give special treatment in its support schemes to those projects of appropriate merit which involve academic-industrial co-operation.

4.30 The corporate tax system offers one means of encouraging companies to undertake particular types of activity, but we consider that it is not an appropriate instrument to encourage HEI-industry collaboration. First, tax incentives might bias industrial R & D effort towards HEIs when some work might best be done in-house. Secondly, such measures would bear very unevenly on companies because of their widely differing tax structures — a large number of firms pay no corporation tax. Thirdly, HEIs coexist alongside other organisations undertaking contract research for industry and the competition between them must be fair.

4.31 We have identified problems in establishing collaboration between industry and HEIs. In part these are attitudinal, but we are convinced that there are other elements as well. First, in some areas, academics and industrialists are unable to formulate the problem on which they could collaborate. For example, an academic department may have considerable understanding of an 'ideal system' whereas the system on which a company needs help is not 'ideal'. Neither party finds it easy to define the problem in terms which the other can understand. This kind of conceptual difficulty could be overcome if each party could, for a while, breathe the culture of the other.

We therefore recommend that SERC and the Royal Society more vigorously promote their fellowship scheme for mobility between firms and HEIs and that other bodies well-placed to promote mobility establish similar schemes.

The second, administrative difficulty concerns the conditions under which an academic could take an extended period of leave in industry to see an idea through to commercial application in a firm, perhaps one that he himself has helped to found. The key feature seems to be to provide an element of financial security while trying out such a venture.

> *We therefore recommend* that DOI establish a scheme whereby academics can take extended 'exploitation leave' in small companies with a guaranteed right of return to their institution, with DOI paying for a substitute member of academic staff during their absence from the institution.

The role of Government

4.32 We have indicated how the Government can give financial support to links between HEIs and industry. But we feel that more needs to be done to improve awareness among both academics and (more particularly) industrialists of the benefits of collaboration, both to the parties concerned and to the nation. In the past, Government 'awareness campaigns' with strong involvement by Government Ministers have been powerful instruments of change.

> *We therefore recommend* that the Government mount a campaign, with active Ministerial involvement, to improve awareness of the benefits of academic-industrial collaboration and of the measures available to encourage it.

4.33 We are concerned that much of our evidence revealed a gap which still exists between the interests of DOI and SERC. (The same will apply to other Departments and Councils.) Their policies and practices do not match well enough. Their respective criteria for assessing projects are fundamentally different, and this can lead to turgid administrative procedures when funding is sought from both bodies for an apparently meritorious joint academic-industrial project. There is a continuous spectrum of possible academic-industrial partnerships but no commensurately flexible arrangement by which they can be funded. Many people found the present assortment of schemes confusing. Only the Teaching Company scheme is designed to provide support from both DOI and SERC for collaborative work, and its success shows how productive joint activities can be. The acceptance of the Alvey Report's proposals on information technology is a further step in the right direction. But more is still to be done. The Co-operative Grants Scheme (for example) should be two-way, enabling the industrial partner to receive financial encouragement to carry out its share of a genuinely joint project, and we recommended a mechanism in paragraph 4.29. SERC's directorates, with DOI representation on their management committees, go some way to bridging the gap and there is a need for a wider development of such schemes across disciplines; but we have heard that cross-representation by officials between DOI and SERC committees is somewhat ineffective.

4.34 The difficulties over project funding reflect a more general question: the basis on which DOI and SERC draw the dividing line between them. This appears to be drawn on the basis of where work is carried out. In 1981/82, DOI spent only £2M in HEIs out of a total science and technology budget of £212M; SERC spent none of its £217M directly in industry. We understand that present DOI policy reflects the Department's role as a 'proxy' customer for R & D on behalf of industry; it has few regulatory or procurement activities, and commissions little research for its own purposes. It has chosen to reinforce market forces through industrial members of Research Requirements Boards who appraise proposals for work from Research Associations, Government Research Establishments or (notably) from firms themselves. But we see no reason in principle why DOI, as a proxy customer for R & D, should not include HEIs in the range of bodies who might approach it with proposals likely to benefit industry.

4.35 As a result of this division of responsibilities, there is a significant body of research, which HEIs are well equipped to carry out, which DOI considers too 'basic' and SERC too oriented to a specific industrial problem to merit support. Much of this might be described as 'enabling science' — work needed to improve basic understanding in defined areas so that products or processes can be optimised for subsequent industrial development. Without the enabling science, progress would not be possible; with it, there is a chance of progress. The research in such areas needs to be of high quality and elegant, but other things being equal, a hard-pressed Research Council will tend, quite reasonably, to support research proposals which offer new horizons and the prospect of new fields of endeavour rather than (equally high quality) proposals which primarily fill gaps in understanding. Funding of this type of work, we feel, is appropriate to DOI through a mechanism incorporating advice from SERC.

4.36 SERC has, in recent years, identified and funded a good deal of industrially-oriented work in HEIs, and this activity should continue. But we feel that SERC should not extend its funding further in this direction; such initiatives as SERC and DOI might jointly devise in future for the support of industrially-oriented research in HEIs (or indeed joint projects between firms and institutions) should be funded primarily by DOI, although SERC would be well-placed to administer the schemes. We have particularly in mind the establishment, in areas of national importance, of specially promoted programmes and directorates, largely funded by DOI, to promote R & D carried out both in firms and HEIs.

A principal recommendation **is that DOI and SERC should collaborate more closely in supporting both joint activities carried out by industry-HEI partners and industrially-oriented work in HEIs (we see SERC's directorates as a model); that DOI should provide most of the funds for new initiatives in this area, although SERC might administer the schemes; and that other Research Councils should consider with appropriate Government Departments the introduction of joint schemes for the support of academic-industrial collaboration.**

4.37 In summary, we conclude that SERC's efforts in supporting industrially-oriented work in HEIs has not been matched by other agencies or by industry and that, in consequence, the associated fundamental work — for which it is the major sponsor — may be under unreasonable pressure. SERC would be justified in expecting that funds for the support of new initiatives in academic-industrial collaboration would largely come, first, from DOI and other industry-sponsoring departments and, secondly, from industry itself as the influences of this report, the Government awareness campaign and the 'industrial seedcorn fund' are felt. The consequence for DOI would be an increase in its science and technology budget, through accepting the support of industrially-oriented work in HEIs and contributing to the 'industrial seedcorn fund'. We would expect DOI to transfer the necessary money from its present support provisions for traditional industries. We would see such a transfer from 'sunset' to 'sunrise' industrial activity as being entirely consistent with the Department's published strategic aims.

4.38 As an associated concern, there is clear evidence that improvements are needed at all levels in the supply of information and marketing of academic capabilities to industry. First, a comprehensive national database is needed, itemising the expertise, services and research programmes available in HEIs, classified according to technology or product area, as well as institution, and aimed at facilitating contact between individuals. The database should be comprehensive, accurate and promptly updated. It should be publicly accessible (possibly by Prestel) with a modest charge per 'page' of information, any deficit being met from SERC or DOI funds. SERC might assume management responsibility for the scheme, with its setting up and operation contracted out to a private sector company. The database might also include the information on public sector capabilities currently available through the DOI's Technical Advisory Point.

> *We therefore recommend* that the SERC, in collaboration as appropriate with DOI and others, establish a national database of HEI research capabilities, accessible to the public by means of viewdata.

4.39 A logical adjunct to the database would be a national system of regional information and awareness brokers on the present SERC model. Their task would be to provide advice where needed on the expertise identified by a search of the database, and to promote a simplified package of support schemes for innovation and academic-industrial partnerships. The cost of the broking system might be borne by DOI and SERC jointly. Other organisations such as BTG (as mentioned in paragraph 4.28), the Design Council and local authorities may wish to associate staff with the brokers or to employ them part-time as agents. We envisage the broker himself being of high calibre and wide experience in industry, capable of dealing with firms, HEIs and other organisations at top level; he would have a small unit of seconded professional staff to support him and to provide regionally such professional services as HEIs demand or public sector bodies wish to supply. At regional level, groups of HEIs might choose to market their capability jointly, in collaboration with their regional broker.

> *We therefore recommend* that the DOI and SERC jointly set up a national system of regional brokers as an adjunct to the national database and to promote the support available for innovation and academic-industrial partnerships. Other public sector organisations should be enabled to employ the brokers part-time as agents for their own regional activities.

4.40 Finally, we stress again the urgent need for action to encourage productive links between industry and HEIs. We consider that the measures advocated in this report will encourage links, to the benefit of HEIs, industry and society.

Annex 1

Summary of United Kingdom written evidence

Introduction

1. As a part of their enquiries, the Working Group sought views and opinions from the polytechnics, universities and Scottish Colleges of Technology, a broad spectrum of interested third parties, and over one hundred and fifty companies who had made enquiries about joint research or development funding to the Science and Engineering Research Council (SERC).

2. The enquiry request consisted of a letter from the Chairman of the Working Group to the head of each organisation asking about —

- their general views on co-operation between industry and higher education, the advantages and disadvantages, problems and opportunities;
- any barriers or disincentives to the formation and extension of co-operative arrangements and the scope for their dismantling;
- what should happen in this field of co-operation and how to bring it about.

In addition, firms and higher education institutions (HEIs) were asked about the extent of their co-operation, in terms respectively of their annual outgoings to higher education and industrial receipts, and any special arrangements for co-operation which they made or participated in.

3. These approaches were not designed to constitute a complete national survey but to identify the main aspects of industry-education links today and perceptions about them. Over 240 responses were received, of varying length and detail. (Respondents are listed at Annex 4.) The responses were analysed for the Working Group by the Technical Change Centre, London whose report was an important input to the Working Group's thinking.

4. 201 submissions were included in this analysis, others arriving after a cut-off date being dealt with separately. Among those included were 57 from universities and university colleges (85% of those approached), 28

polytechnics and Scottish central institutes (76% response), 85 industrial companies (56% response) and 31 from interested third parties including the Research Councils and the learned and professional societies.

5. This annex contains an abridged version of the Technical Change Centre's report. The balance of presentation may therefore be somewhat different from the Centre's report to the Working Group, but we hope this has been redressed in discussion elsewhere in this report.

Summary of the Technical Change Centre's Report

Advantages of HEI-Industry Links

6. There was unanimous agreement from all respondents that HEI-industry links are beneficial to both parties, and while the benefits might vary through time, both parties gain in the long-run from working together. The general advantages concern the input and outputs of both the industrial and HEI systems. Industry gains useful ideas, access to experts and to unique resources and future employees, while HEIs also gain useful ideas, stimuli, and enhancement of teaching.

7. Financial advantages could be identified by both parties in terms of generating revenue for universities but not so for polytechnics, and of giving industry access to high quality, low cost research facilities and expertise. However, HEIs also saw disadvantages in industry using their facilities because of their 'low cost'. It was not stated if higher charges would discourage industry from using them, or if, because of little demand, low prices had to be charged to attract partners.

8. Interested third parties suggested that HEI-industry links were improving (information on special arrangements made by both HEIs and other parties tended to corroborate this), and that such links were vital for both industry and HEIs as joint partners, and also for the economy as a whole.

Disadvantages of HEI-Industry Links

9. Four areas of general agreement exist as regards the disadvantages, barriers, disincentives, and problems of HEI-industry links. First, the structure of HEIs in particular was seen as inappropriate to undertake many forms of industrial work. This barrier could be overcome with the development of specialist units, by the release of staff to undertake research work full-time, and by the recognition of the validity of industrially-oriented work for appointments and promotion.

10. Second, the problems to which industry seeks solutions are frequently of a short-term and practical nature, and may not easily be placed within a long-run research perspective. Furthermore, industry seeks rapid, workable solutions, not perfect answers. This approach militates against academic excellence. It was seen as vital not to allow either the teaching or the basic research work of HEIs to be compromised by engaging in increasing amounts of industrial work. While, it was generally agreed this was a barrier to greater HEI-industry links, it was not seen as insurmountable. HEIs were well suited to undertaking specific types of research.

11. Third, poor communication and misunderstandings between industry and HEIs were seen as a major barrier by both parties. Each carried misconceptions of each other, yet in those cases where collaboration did exist any misconceptions had soon been dispelled. In particular it was felt that there is a need to identify HEI expertise and facilities which could be used by industry and actively to promote this information via the SERC's regional broker scheme. Similarly, it is important that the needs of industry be identified and communicated to HEIs. Incentives must exist, however, for both parties to ensure that such a 'marriage broking' service works.

12. Fourth, it was generally agreed that the existing monopoly role of the British Technology Group is in urgent need of revision — this monopoly acts at present as a disincentive to HEIs, and to industry. However, it was also generally agreed that there is a role for the BTG though at present it is not readily apparent what this role should be. If a more strategic approach to research funding was undertaken at a national level a role for BTG might emerge.

13. No common agreement emerged as regards confidentiality. The HEIs suggested that confidentiality was a problem in some cases, whilst in others it was not so. Not only did this depend upon the nature of the problem being tackled, but also the company involved. A number of HEIs indicated that North American and European companies were less worried about confidentiality than their UK counterparts. The validity of this assertion is open to doubt and cannot be verified by the available data.

14. The disadvantages indicated by HEIs and industry were not seen as insurmountable, and in numerous cases what appeared to be a problem in one instance was not so in another. How real many of the problems were and how often they had been encountered could not be identified from the available data. It appeared though that with commitment and a positive attitude on both sides no problems or barriers existed, though disincentives (especially financial) would probably remain for the present.

Financial Extent of HEI – Industry Links

15. The data are neither comprehensive nor detailed enough to allow a true measure of HEI-industry links. The sums involved are considerable and it would appear that the HEIs receive around £35-40M per annum from industry. On average each polytechnic received nearly £80,000 per annum from industry, while the comparable figure for universities was over £600,000. These two averages relate to the most recent years for which data are available which are 1981 and 1982. A detailed analysis of the links between HEIs and industry, if they could be quantified, would probably reveal that the extent of funding is well beyond the £40M level indicated above. Not included in this figure are the provision of materials, equipment, and staff time. Also excluded are large donations (non-research specific funds) for research laboratories.

Nature of Existing Arrangements for HEI-Industry Links

16. Most HEIs have now established some way of liaising with industry, which ranges from institution wide liaison units to specific subject-based units. These arrangements have been greatly enhanced by the activities of the SERC via its schemes for Collaborative Awards and Grants, the Teaching Company Scheme, and the Regional Broker Service. Enough examples and experience have accumulated to allow further modifications and developments to current practices to be made. Despite the provision of both new units and departments in HEIs and the promotion of collaboration by the SERC, the most effective means of liaison was via individual consultancies and existing teaching programmes. Without individual commitment and trust on both sides, the provisions indicated above would make little impact.

17. Within industry few formal arrangements have been made for liaison with HEIs for research purposes. It is much more common to find graduate recruitment officers who will co-ordinate the sponsorship and recruitment of new graduates. Only in the largest firms is the organisation of the work with HEIs sufficiently large to warrant a full-time member of staff. Time is also a major constraint within industry, preventing greater collaboration with HEIs. The recent cutbacks in industry have not only reduced the timescale of research still further, but have also cut across many well established personal links.

Proposals for Improving HEI-Industry Links

18. The proposals put forward by each of the four categories of respondents: — universities; polytechnics and the central institutes in Scotland; industry; and third parties — are of two main types: the general, and the specific. The proposals put forward by all parties can be put under six headings: finance,

liaison mechanisms, staffing, national R&D structure, communications, and the SERC.

19. *Finance:* It was generally agreed that the existing funding arrangements for HEI research need to be reorganised, and to operate on a more coherent and strategic basis. In particular, greater involvement of the Department of Industry is needed, especially if specific opportunities emerging from existing research work are to be built upon. Greater involvement of the Department of Industry was also seen as a means of promoting strategic research (by expanding its present involvement with the directorates of the SERC) and of identifying research priorities.

20. In order to enhance existing research relationships, new financial incentives should be introduced. Few specific suggestions were made, but it was felt that the exploitation of HEI ideas for the benefit of the HEIs (not BTG) and any company concerned would help, and so would tax and VAT concessions on joint industry-HEI research work.

21. *Liaison mechanisms:* Existing mechanisms should be developed, in particular by the liaison unit system and/or by science parks or innovation centres. Science parks or similar schemes were not mentioned by any of the industry respondents. They may require substantial financial commitment and the co-ordination and support of a third party. The plan of the Scottish Development Agency is to harness the resources of the Universities of Glasgow and Strathclyde at the West of Scotland Science Park. The Agency is also involved with similar work at the Universities of Aberdeen and Heriot-Watt. There is no equivalent to the Agency in England to perform a similar co-ordinating function.

22. *Staffing:* All parties agreed it is important that there should be staff exchanges between industry and the HEIs. These could be facilitated by sabbaticals for industry and HEI-based staff. Exchanges would also be made easier if the career structures in industry and HEIs were similar.

23. *National R & D structure:* While some industry respondents felt that there should be less direct Government involvement in R & D, the weight of opinion from both the HEIs and the third parties was that existing investment requires much greater co-ordination. A common policy is needed for each of the parties involved, i.e. BTG, Departments of Industry and of Education and Science and the Research Councils. It is important that a coherent policy be established and that complementary (not competing) strategies be developed.

24. *Communications:* By far the greatest area of agreement was on the need for an improved means of communicating between industry and the HEIs. The means most frequently suggested was the establishment of an active resource register (database) to provide a way of matching HEI-based ideas, resources and experts with the needs of industry.

25. The exchange of staff (noted above) was also seen as a potent means of communicating and of sharing the understanding of each others' worlds.

26. *SERC:* The SERC was seen as already having an important role in establishing and developing links between industry and the HEIs. Particular mention was made made of the Collaborative Awards and Teaching Company Schemes both of which should be expanded. The Regional Broker Service should also be expanded and might be able to take on the development and operation of the database scheme to enhance communications (see above).

Annex 2

Some overseas arrangements for academic-industrial collaboration

The Federal Republic of Germany

1. There was a strong tradition of links between universities and industry in engineering until the 1960s. University teaching posts were only available to people who had spent some time working in industry, and this provided a good personal basis for contacts at a later stage. The increased demand for university teachers caused by the expansion of the universities in the 1960s meant that this requirement had to be dropped and the tradition has now to some extent been broken.

2. There is a general feeling that more should be done to improve contacts between industry and universities: particular areas of difficulty are seen as:

— the traditional independence of a German professor means it is difficult for his employer, the university, to force him to become involved in such activities;

— the institutional structure of German universities makes it difficult for them to take on contract work for industry;

— there is a feeling that universities should be engaged only in fundamental and not applied research.

3. Efforts have therefore recently been made to involve universities with local industry in their areas:

— universities have set up contact offices to help industry get in touch with their experts and to assist with the arrangement of joint research projects;

— other technology transfer agencies (eg those associated with chambers of industry and trade) have similarly tried to mediate between universities and industry;

— the Research and Technology Ministry has tried to involve appropriate university departments with industry in research and development consortia.

4. Many of these measures are too new for their success to be assessed, but some aspects of industry/university interaction appear to be functioning well. Examples are:

— the interaction of the older technical universities with large industry in traditional areas of technology. (The good relationship of the Technical University of Aachen with heavy industry in the Ruhr, and the Munich Technical University with Siemens are good examples.);

— The Fraunhofer Society Institutes are often successful in drawing on knowledge in university departments. The relatively high status of engineers means that such managers can often also take leading positions in firms.

5. But there are other less satisfactory aspects:

— universities have not been good at grasping the industrial significance of some new technologies (eg biotechnology) and carrying their knowledge in these areas into industry;

— in spite of the contact offices many small and medium sized firms still do not consider universities as a source of useful knowledge;

— universities often have difficulties arising from institutional constraints in carrying out joint research with companies.

France

6. In July 1982 the French law for research and technology was adopted by the National Assembly. The law was based on the report of a national colloquy on research and technology held the previous January. The law is essentially concerned with technology, and one of its main objectives is to 'open up' French science to industry. The key provisions of the law in this respect are:

— the creation of regional committees for research and development which will have their own budget and a degree of autonomy to develop regional science policies;

— the creation of a new legal category of organisation, 'établissements publics à caractère scientifique et technologique', which will be applied to organisations such as CNRS. The formula will give these bodies an explicit duty to attempt to apply their work, to publicise their research and to train and educate researchers;

— a second category of organisation, 'groupements d'interêt public', is created to allow such bodies as CNRS, for a limited period, to form profitable liaisons with industry;

— in a kind of inclusive job description, the 'mission' of a researcher is defined as the development of knowledge, its transfer to industry and society, its popularisation, the education and training of young and old and administration;

— all government researchers will become 'fonctionnaires', giving them the envied security of civil servants which, hitherto, only university staff have enjoyed.

7. The following are the chief means by which university/industry links are encouraged in France:

— French firms pay a payroll tax to the Government in respect of training (taxe d'apprentissage). However, this money may be retained by the firm if an individual is trained in-house, or paid to a public research institute if the training is undertaken there;

— a firm may pay a publicly-funded institution to undertake some problem-solving research (usually short-term) or for the use of the institution's facilities (eg for testing equipment);

— a firm may contract with an institution to finance longer term work which may be to start a new line of research to look at a sideline of an existing programme, or simply to work on an interesting idea/project suggested by an academic. More likely than not the contract will be used as a means of funding postgraduate students or fellows (students who already have a third cycle doctorate and no longer qualify for a state grant). The contract will also cover running costs, materials, and perhaps travel.

— CNRS contracts: an academic may interest a firm in a university project, and the firm signs a contract with CNRS to fund the work. The research laboratory spends the money and publishes with the sponsor's permission.

— State aid for industrial projects: an institution and an industrial partner obtain government funding for a large project. This provides three-quarters of the university's costs and one-half of the firm's costs. Running costs and research students' grants are included. This is a previous DGRST scheme and it is not clear how it will operate under the Research Ministry.

Japan

8. University research does not seem to have the same status or role as a source of innovation as is the case in the USA and Europe. Only a modest proportion of Japan's universities enjoy a reputation for high grade research which is relevant to industrial innovation. Firms do not generally look to

universities for their ideas, the larger and more important of them preferring to carry out their own basic research. (Some university professors in Japan have accused firms of suffering from a 'not-invented-here' syndrome.)

9. A further factor is that the Ministry of Education, which directly employs university staff (unlike the equivalent situation in the UK) actively discourages direct links between academics and companies. Consultancies are forbidden in state universities (although not in the smaller private ones) in case these lead to nepotism in obtaining appointments.

10. The most effective channel for university/industry collaboration in Japan is through informal personal links. Compared with other countries, Japanese graduates stay in closer contact with each other throughout their professional careers. This leads to valuable relationships between academics and industrialists, particularly in research. This is reinforced by the role university professors play (as employees of the Ministry of Education) in the establishment and implementation of national research programmes, for example, the VLSI project and the 5th Generation Computer project. These national programmes, which are normally under the direction of MITI or the Science and Technology Agency, have extensive industrial participation. The presence of academics in the controlling bodies means that research results are effectively exchanged between companies and universities.

11. As direct Government employees, university staff in Japan are not allowed to profit from the commercial exploitation of their ideas. This acts as a considerable disincentive to taking out patents and promotes dissemination of results through open publications. Currently academic researchers are being encouraged to take out more patents and at least two universities have set up special offices to arrange this (Tokyo Institute of Technology and Tohoku University). The outcome of this could be to make research results more attractive to firms, which can take licences.

12. Although direct links between companies and university staff are discouraged for the reasons mentioned above there are many cases of informal collaboration. For example, the Electronics Department at the University of Tokyo has currently 5 visiting researchers from well known Japanese electronics companies for periods of 1 or 2 years. Also the Department receives grants from at least 10 companies which are used for purchasing equipment. The arrangement for visiting researchers from industry has some similarity to the UK's Teaching Company Scheme, but the emphasis seems to be on the industrialist working in the university rather than the other way round.

13. Collaboration between companies and university departments is also helped by the practice of using universities as shop windows for new equipment (often given or sold at very low prices). Through this firms receive feedback on the operation of new equipment and often valuable suggestions for modifications and extensions. Instances of this practice are computers (Fujitsu), telecommunication receivers (NEC) and Rankine cycle turbines (Mitsubishi).

14. In addition to these general collaborations there are limited examples of university developments being directly commercialised by companies. This has been the case in Tokyo University's robot developments (Toshiba) and in some biotechnology developments. These activities are promoted (although not necessarily in the examples quoted) by the Research and Development Corporation of Japan which has a similar role to the NRDC with comparable funding. However, it does not have any direct right to the exploitation of inventions by academics. Currently about half (123) of RDCJ's portfolio of projects concern the development of university research.

15. As in many countries the Japanese Government is encouraging closer working relationships between universities, industrial firms and Government institutions through the research park type of development. The so-called 'Science City' at Tsukuba was established some 10 years ago and now houses half of Japan's Government research institutes and 2 universities. So far companies have been slow to set up research facilities at Tsukuba, possibly because it is some distance outside Tokyo and road and rail communications are not very efficient. Time will tell whether this experiment will have the same success as Stanford, Boston and Cambridge.

16. In summary, university/industry links in Japan are fairly strong and operate mainly through personal relationships and involvement in national research programmes. Universities are being encouraged to patent their research but direct financial ties with companies are not permitted by the Ministry of Education. The practice of having visiting researchers from industry in university departments for periods of more than one year is a strong factor in ensuring that company and university research are closely linked.

United States of America

17. The overall scale of university-industry collaboration in the United States has been described in a recent report by the National Science Board (Fourteenth Annual Report) which identifies academic institutions as the

performers of 9% ($6,600M) of the nation's research and development ($69,000M) in 1981. Returns available to the National Science Foundation indicated that approximately $250M (3.5%) of the academic research and development budget was provided by industry. This percentage has been fluctuating but the cash sum has doubled in real terms since the mid-1960s. The National Science Foundation speculates that the true percentage might be over 6% when donated equipment, undeclared sums and the research share of philanthropic gifts ($780M from corporations in 1980/81 of which about a third is earmearked for research) are taken properly into account. Of the top 200 academic research institutions, 25 had industrial support totalling more than 10% of their research and development budgets.

18. Because of the size and diversity of the United States higher education system, virtually every type of university-industry collaboration can be found. One general feature is that faculty staff are allowed and encouraged to undertake consultancy for pay. One day a week is generally held to be compatible with faculty duties. In addition, the widespread practice of basing salaries on the teaching terms, amounting to 9 months of the year, leaves the academics free to bid for research money from the university or national agencies, or to undertake business activities, for the remainder of the year. A recent study of nearly 500 sizeable company-academy collaborations (carried out by the Centre for Science and Technology Policy, New York University and published by the National Science Foundation) found that three-quarters were based on previous consultancies. In the overwhelming majority of cases, the cooperative research programmes were initiated by the academic partner though the first, consultancy, contact may have come from the companies.

19. The most spectacular results of university-industry links are provided by the economic success of regions where they are strong. The chain of new companies, founded in relatively cheap premises around Route 128 in Boston, started with graduate students and ex-faculty members from the Massachusetts Institute of Technology providing services for the university itself and then broadening into nationally competitive companies. The electronics industry that originally 'spun-out' of Stanford is another example where graduate students, assisted by their faculty staff working part-time or on consultancies, have played a major role in operating new industry which in its turn has encouraged the relocation of existing companies into what is now the world's centre for microelectronics.

20. More recently, a number of very large, existing companies, often in the health products sector, have made long-term arrangements to support university research. Hoechst, the West German pharmaceutical company,

will invest approximately $65M over the next 10 years in a new research department at the Massachusetts General Hospital. DuPont will be putting approximately $6M over 5 years into a new genetics department at the Harvard Medical School. Monsanto and Rockefeller University have agreed a $24M programme over five years based on photosynthesis and related subjects. A consortium of electronics and computing companies have formed the Semiconductor Research Co-operative which will place research contracts valued at approximately $20M in selected universities over the next two or three years. Exxon and the Massachusetts Institute of Technology have agreed a $10M programme in combustion research.

21. Most of the big partnerships are based on non-exclusive licensing. The companies have the right to second staff to the research centre, thus ensuring transfer of the know-how, and there is typically the possibility of a one or more month delay to publications to allow the companies to file patents and to check for the possible disclosure of proprietary information. The practice has grown up of the partners publishing the terms of their agreement to help forestall uninformed criticism of contraints on academic freedom. Indeed, the big partnerships seem to give a high degree of freedom to the research leaders. By backing a good team on fundamental studies in an important area, and by enhancing the ability to recruit graduate students and to second company staff, the industrial partners believe that they are laying down a sound medium to long-term investment.

22. The National Science Foundation has three principal schemes which foster university-industry links. The *Industry-University Co-operative Research Programme* (IUCR) is a variant on the standard NSF grants scheme whereby the funding to a joint university-company project may cover all the normal university research costs plus up to 50% of the collaborating company's costs of participation (or 90% if it is a small business). The projects need joint sponsorship within NSF by the appropriate subject Division (eg chemistry), which conducts a normal peer review evaluation, and by the Division of Industrial Science and Technological Innovation. The award can be made to the company or the university, with the award holder subcontracting to the other party. It is left to the co-operating partners to reach their own agreement on the disposition of patent rights prior to submitting a proposal. NSF expenditure on the scheme in 1981 was $8M.

23. There are currently half a dozen *Co-operative Research Centres* operating. Some pump-priming support, and a brokerage/advisory service, is given by NSF to interdisciplinary research centres whose main funding will ultimately come from a consortium of companies. The NSF's funding is

phased out within 5 years. The intellectual property rights stay with the centre but all members of the consortium are given non-exclusive and royalty-free licences. Publications may be delayed by up to one year. A major benefit for the companies is the recruitment of graduate students from the centres. The NSF sees its long-term role as establishing the canons of good practice which lead to successful centres, with the hope that they will be emulated independently. The current NSF budget is currently around $2M per annum.

24. The *Small Business Innovation Research* (SBIR) programme is specifically aimed at research and development within small (up to 500 employees) companies. Each project is expected to have three phases —

Phase I — contract for six months for a feasibility study. Contracts are awarded competitively against NSF's statement of requirements and are up to $50,000;

Phase II — main contract, typically over 1 or 2 years and up to $500,000, awarded to most promising feasibility study which also demonstrates company's competence *and* commitment of venture capital for subsequent commercial exploitation of R&D;

Phase III — commercial exploitation entirely funded with private capital.

NSF Programme Directors put out a 'Programme Solicitation' each year with descriptions of the areas in which they wish to see research done. The applications are first screened by NSF staff and then go to a peer review process for the technical and scientific merit to be ranked. The 1982 approval rate was 1 in 8. Approximately $20M has been put into SBIR by the NSF since 1977 and the private follow-on money is already estimated at $47M, of which $41M is associated with the $5.3M programmes which have passed through phase II. Thus the multiplier appears to be factor of 8. The companies concerned have shown a 125 per cent increase in employment since 1977. Because successful bids to the SBIR programme depend on the research itself being of merit, the programme has encouraged existing small businesses to use academics as part-time employees or consultants and has also encouraged the growth of new businesses out of campus skills.

25. There has been a series of new legislative steps over the last four years in order to encourage innovation. The *Economic Recovery Tax Act* (1981, Public Law 87-34), for example, aims to stimulate increased R&D expenditure above historic levels. The credit is also given for extra-mural expenditure (though only 65% of costs are allowable, to take out the non-R&D overheads of the contractor). There are also provisions for increased allowances on donated equipment and a faster depreciation (3 years instead of 5) on installed

research equipment. Uncertainties about the formation of research consortia have been clarified by the *Antitrust Guide Concerning Research Joint Ventures* which the Department of Justice published in 1980. However, the two main steps of interest to the ACARD study are the *Uniform Federal Patent Policy Act* (1980, Public Law 96-517, known as the Bayh-Dole Act) and the *Small Business Innovation Development Act* (1982, Public Law 97-219).

26. The Small Business Act requires that the ten federal agencies with the major share (99%) of the Government's R&D budget should spend at least 1.25% of their respective R&D budgets through contracts to small businesses. Most will reach this level over three years though Defence, with the largest budget, has four years to achieve the target. By 1987, approximately $500M per annum will be in the programme. The approach is modelled on the pioneering SBIR programme which the NSF has been running since 1977 and will include the same three phases. On the one hand, the national legislation could be expected to reduce the direct funding into universities because the small business funding may in part come from other extra-mural spending, but on the other it is also expected to increase company-academy links because the former need to exploit the skills of the latter in order to join the small business programme. Thus consultancies, joint ventures, and spin-off companies are all likely to be encouraged.

27. The Bayh-Dole Act is based on studies carried out over a number of years. In 1974, the President made a statement on Government patent policy which stressed the need to exploit better the inventions arising from research funded by Government. A national committee on University Patent Policy then reviewed the various practices in the Federal handling of intellectual property rights and recommended (July 1975) that —

> 'executive agencies be advised to adopt policies and regulations recognising that the public interest will normally best be served by allowing educational institutions with a technology transfer programme meeting the general criteria [see below] to retain title to inventions made in the course of or under any Government research grant or contract. These policies and regulations should require the use of Institutional Patent Agreements with the educational institutions.'

The proposed general criteria for a suitable technology transfer programme included —

— a formal patent policy administered on a continuous basis by an officer or organisation responsible to the institution;

— assurance that university employees would be legally obliged to assign inventions, made under Government funding, to the institution;

— a programme for licensing and marketing inventions (expected to be normally non-exclusive unless it would seriously prejudice exploitation and then licences to be for fixed duration);

but the subsequent legislative enactments did not require an Institutional Patent Agreement over and above a fairly straightforward set of conditions attached to federal grants and contracts.

28. The main outcome of this activity, and parallel developments elsewhere on stimulating innovation and small businesses, was the 1980 Bayh-Dole Act, which, *inter alia,* established uniform patent procedures for all Government-funded R&D carried out in universities, other non-profit-making organisations, and small businesses. Such contractors may elect to retain title to inventions. There are certain exceptions (eg in contracts to run a Government facility or on grounds of national security); there is a requirement to disclose inventions to the funding agency; and there are sundry 'march in' rights whereby title can be forfeited (eg when there has been no attempt at exploitation). There is a clause on 'preference for United States industry' which says that there shall be no exclusive licence to a third party unless that party agrees to the products being 'manufactured substantially' in the USA. There is a waiver, however, if reasonable but unsuccessful efforts have been made to find a licensee who would manufacture domestically.

29. The implications for universities will be far-reaching. All the largest research institutions have hitherto had their own arrangements for handling patents and licences, as there is no national agency such as NRDC, but much greater emphasis has now been put on this as a mechanism for technology transfer. The Corporate Relations officer is a new and respected colleague on many campuses. Increased commercial discipline and a better general awareness of the value of intellectual property amongst faculty staff, as well as better exploitation, will be encouraged by the legislation.

Annex 3

Details of the Industrial Seedcorn Fund

1. In paragraph 4.17 of the report, we recommend that the Government establish an industrial seedcorn fund to be divided among higher education institutions (HEIs) in proportion to their eligible earnings. We also proposed guidelines for HEIs in using their allocations from the fund. In this annex, we suggest some further details about the operation.

Eligible earnings

2. HEIs' earnings from the private sector and the public trading sector in the UK and overseas contracts, consultancies and investigations would be eligible. Earnings from teaching and training would be excluded. Gifts, endowments and grants would also be excluded. Eligible sources of earnings include private industry and commerce, nationalised industry and public corporations, but exclude Government departments, Research Councils, charitable foundations and other non-trading public sector bodies.

3. Only cash earnings would be eligible. This would permit both partners to subject the transaction to their own financial control and management procedures. It would, of course, be open to the partners to reach an understanding that the cash should be used by the HEI for a particular purpose, such as the purchase of equipment. Where payment might otherwise have been made in terms of industrial staff time, support might be sought under the SERC/Royal Society Fellowship or other schemes.

4. Earnings by companies wholly-owned by the HEI would be eligible, but allocations from the fund would be made to the HEI, not the company.

Size of the fund

5. We consider that HEIs should receive from the fund 25% of their eligible earnings. The target for earnings should be £100M pa in 5 years time,

compared with £40M pa at present. The size of the fund should increase with earnings so that HEIs continued to receive 25%.

Operations

6. HEIs would declare their eligible earnings at the end of each year. In the subsequent financial year, they would receive an allocation from the fund of 25% of those earnings to be paid in three equal instalments ($8\frac{1}{3}$% each) spread over the year in which the allocation was made and the two succeeding years. This would serve to smooth out some of the fluctuations in earnings and provide some continuity for management purposes. It would also permit a gradual build-up of new activity at the start of the scheme.

Feedback

7. At the time HEIs declare their eligible earnings, they would be asked to report how their last allocation from the fund had contributed to links with industry. This would be useful to the Government in drawing lessons for the future and identifying examples of good practice. The market would monitor the effectiveness with which allocations from the fund were used — HEIs which did not use them to underpin industrial collaboration would be unlikely to prosper in that field in the longer term. Accountability and financial propriety in the use of allocations would be open to scrutiny in the same way as UGC grants.

Annex 4

Organisations and individuals submitting evidence

Industry and RAs

Airtech Limited
Alcan International Ltd
Amersham International plc
Anderman and Ryder Ltd
Automatic Systems Laboratories Ltd
B & W Loudspeakers Ltd
Babcock Power Ltd
Bell and Howell Ltd
Bentley Engineering Co Ltd
Blue Circle Industries plc
British Aluminium Co Ltd
British Gas Corporation, Research and Development Division
British Petroleum
British Railways Board, Research and Development Division
British Robotic Systems Ltd
British Ship Research Association
British Telecom
BSC Sheffield Laboratories
Building Services Research and Information Association
Cambridge Electronic Design Ltd
Cambridge Mass Spectrometry Ltd
Castrol Ltd
CDRA — Federation of Technology Centres
Chloride Technical Ltd
Cole Polymers Ltd
Control Laser Ltd
Corah plc
Cosworth Research and Development Ltd
Courtaulds plc
Crystallox (1982) Ltd
Dalgetty Spillers Ltd
English Clays Lovering Pochin & Co Ltd
Era Technology Ltd
Fairey Aviation Ltd
Ferranti Computer Systems Ltd
Fisons plc, Scientific Equipment Division
Foraky Ltd
Forestry Commision
Fulmer Research Ltd
Gallaher Tobacco Ltd
General Electric Company plc
Genzyme Biochemicals Ltd
GR-STEIN Refractories Ltd
Searle Research and Development
Hall-Thermotank Products Ltd
Hazleton Laboratories Europe Ltd
Impact Finishers Ltd
Imperial Chemical Industries plc
Inco Alloy Products Ltd
Job Creation Ltd
Jones and Shipman plc
Kent Process Control Ltd

LK Tool Co Ltd
Loughborough Consultants Ltd
Lucas Group Services Ltd
Mars Group Services
May and Baker Ltd
McClelland Geotechnical Services Ltd
Merck Sharp and Dohme Ltd
Micro Consultants Ltd
Mineral Industry Research Organisation
Muirhead plc
Myson Copperad Ltd
National Coal Board
National Nuclear Corporation Ltd
Netlon Ltd
Newmarket Microsystems Ltd
Oxford Applied Research Ltd
Oxford Instruments Group Ltd
Oxford Lasers Ltd
Perkin Elmer Ltd
Permali Ltd
Pfizer Ltd Central Research
Philips Electronic and Associated Industries Ltd
Pilkington Brothers plc
Pirelli Ltd
Plessey Company plc
Porth Textiles Ltd
QMC Industrial Research Ltd
R B Hawkins and Associates
Lintech Instruments Ltd
Racal-Decca Defence Systems (Radar) Ltd
Redfearn National Glass Ltd
RHM Research Ltd
Roche Products Ltd
Rockware Glass Ltd
Rolls Royce and Associates Ltd
Shell (UK) Ltd
Shirley Institute
Short Brothers Ltd
Standard Telecommunication Laboratories Ltd
Textile Research Council
Thorn EMI Central Research Laboratories
Thorn EMI Flow Measurement Ltd
Timber Research and Development Association
Transfer Technology Ltd
Turnright Controls Ltd
United Biscuits (UK) Ltd
Upjohn Ltd
Vacu-blast Ltd
Yorkshire Imperial Alloys Ltd

Universities and Colleges

University of Aberdeen
University of Bath
Queens University of Belfast
University of Bradford
Bristol University
Brunel University
Cambridge University
City University
University College, Cardiff
Cranfield Institute of Technology
Dundee College of Technology
University of Dundee
University of Durham
University of East Anglia
University of Edinburgh
University of Essex
University of Exeter
University of Glasgow
Heriot-Watt University
University of Hull
University of Keele
University of Kent at Canterbury
University of Lancaster
University of Leeds
University of Leicester

University of Liverpool
London Business School
University College, London
Imperial College of Science and Technology, London
Royal Holloway College, London
Westfield College, London
Chelsea College, London
Birkbeck College, London
King's College, London
Wye College, London
Queen Mary College, London
School of Pharmacy, University of London
Loughborough University of Technology
Manchester Business School
Manchester University
University of Manchester Institute of Science and Technology
Napier College
University of Newcastle-upon-Tyne
University College of North Wales, Bangor
University of Nottingham
Oxford University
Paisley College of Technology
Reading University
Robert Gordon's Institute of Technology
Royal Military College of Science
University of Salford
Scottish College of Textiles
University of Sheffield
University of Southampton
South West Universities Regional Computer Centre
University of St Andrews
University of Stirling
University of Strathclyde
University College, Swansea
University of Surrey
University of Sussex
New University of Ulster
University College of Wales, Aberystwyth
University of Warwick
University of York

Polytechnics

Bristol Polytechnic
City of London Polytechnic
Coventry (Lanchester) Polytechnic
Hatfield Polytechnic
Huddersfield Polytechnic
Kingston Polytechnic
Leicester Polytechnic
Liverpool Polytechnic
Manchester Polytechnic
Middlesex Polytechnic
Newcastle-upon-Tyne Polytechnic
North East London Polytechnic
North East Polytechnics Mathematical Modelling and Computer Simulation Group
North East Wales Institute for Higher Education
Polytechnic of North London
Oxford Polytechnic
Plymouth Polytechnic
Portsmouth Polytechnic
Preston Polytechnic
Polytechnic of the South Bank
Sunderland Polytechnic
Teeside Polytechnic
Ulster Polytechnic
Wolverhampton Polytechnic
Polytechnic of Wales — Welsh Regional Management Centre

Other organisations

Agricultural Research Council
British Consulate-General — Zurich
British Council — Bonn
British Council — Helsinki
British Council — Peking
British Council — Rome
British Council — Saudi Arabia
British Embassy — Paris
British Embassy — Tokyo
British Embassy — Washington
British Technology Group
Cambridgeshire County Council, Directorate of Planning and Research
Committee of Directors of Polytechnics
Committee of Vice-Chancellors and Principals of the Universities of the UK
Confederation of British Industry
Council for National Academic Awards
Department of Industry
Engineering Council
Engineering Professors' Conference
Fellowship of Engineering
Institute of Chartered Accountants of Scotland
Institution of Chemical Engineers
Institution of Civil Engineers
Institution of Mechanical Engineers
Institution of Metallurgists
Institute of Physics
Licensing Executives Society (Britain and Ireland)
Medical Research Council
Ministry of Defence
National Association of Teachers in Further and Higher Education
National Economic Development Office
Natural Environment Research Council
Royal Society of Chemistry
Science and Engineering Research Council
Social Science Research Council
Society of Chemical Industry
The Royal Society
University Directors of Industrial Liaison Group
University Grants Committee

Individuals

Mr Matthew Bullock, Barclays Bank plc
Dr A J Cochran
Professor J Ffowkes-Williams, University of Cambridge
Mr C O Forestier-Walker, Minola Industries Ltd
Professor K Foster, University of Aston
Professor M W Fowler, University of Warwick
Professor A Gambling, Southampton University
Mr Mark Haggard
Dr E C Hambly
Professor Sir William Hawthorne
Mr G Hayward, Anglian Regional Management Centre
Mr W Herriot, Barclays Bank plc
Dr A Hooper, University of Cambridge
Professor P Hutton, Southampton University

Professor Daphne Jackson, University of Surrey
Dr A T Kuhn, Institute of Dental Surgery, University of London
Dr A Mawson
Professor R A B Mollan, Queen's University of Belfast
Mr C Milner, North East London Polytechnic
Dr W Nixon, University of Cambridge
Professor R J O'Callaghan, University of Newcastle-upon-Tyne
Sir Joseph Pope, formerly University of Aston
Professor K E Porter, University of Aston
Dr D R Rosseinstry and colleagues, University of Exeter
Dr Roy Rothwell, Science Policy Research Unit, University of Sussex
Mr D Rowe, Director, University of Warwick Science Park
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